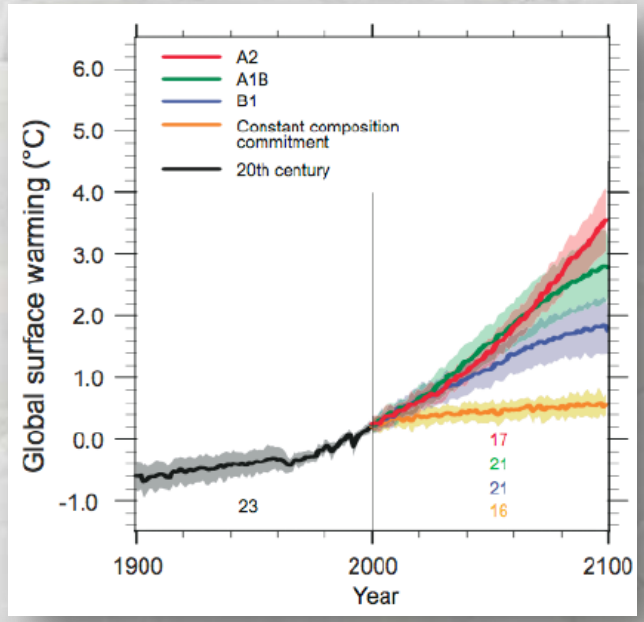
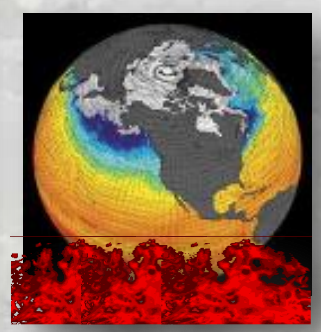
Climate Change as a 21st Century Strategic Context for Salmon Conservation & Adaptive Management



Dan Isaak, US Forest Service
Rocky Mountain Research Station



General outline:

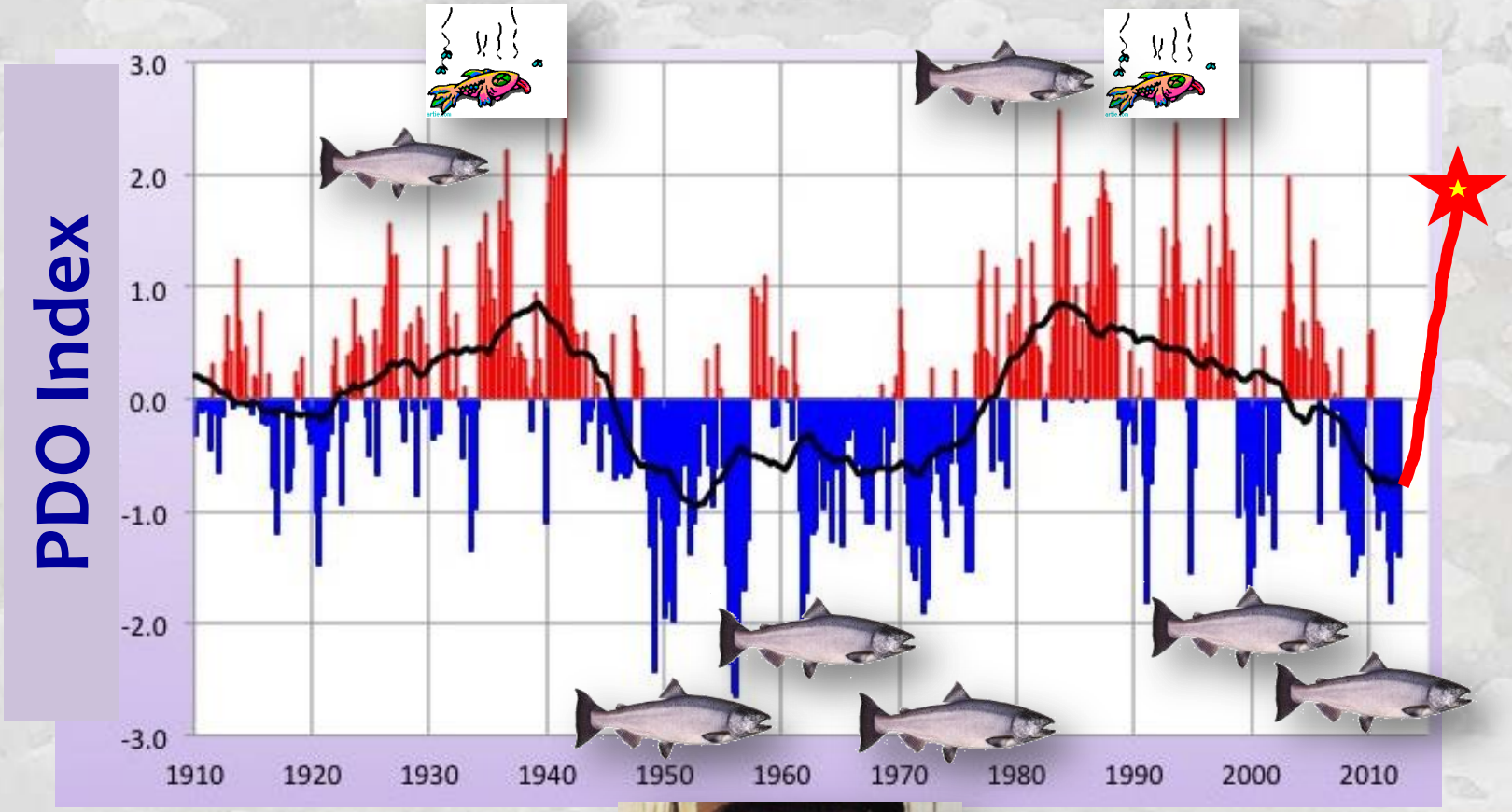
1) Is 2015 an anomaly?

2) 2015 in a climate change context

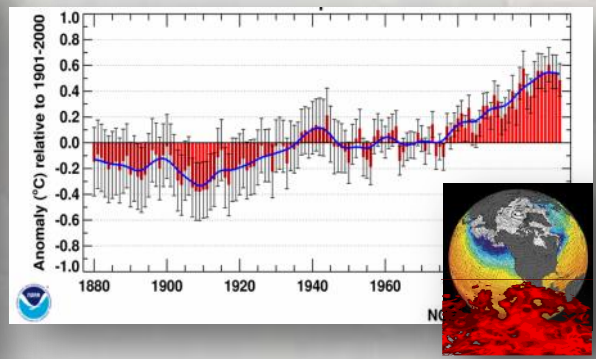
3) Adaptation options for fish & people

4) Building climate information systems to assist with strategic & tactical decision making

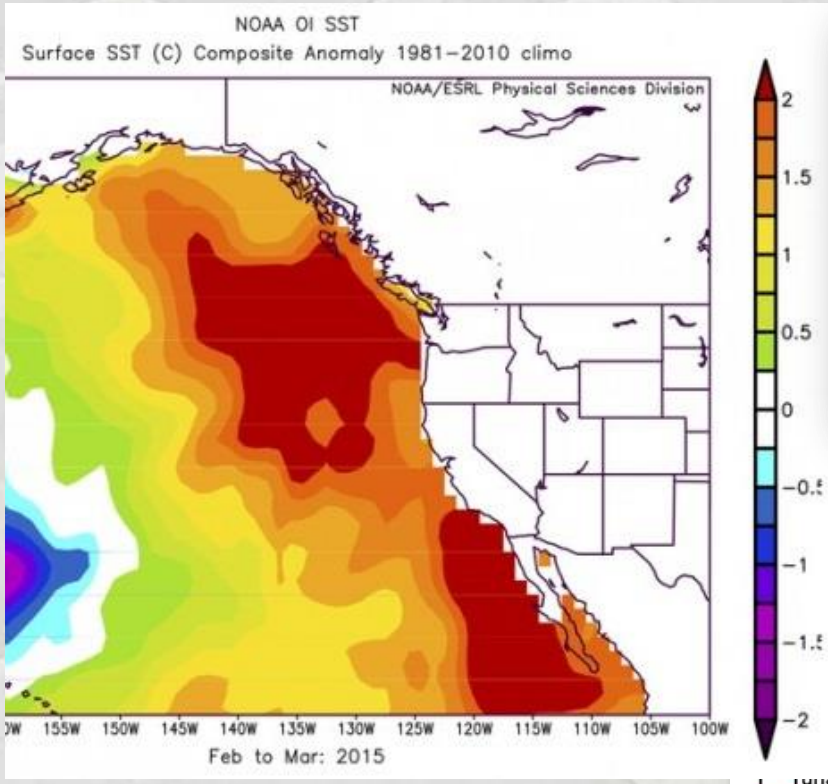
PDO Climate Cycles

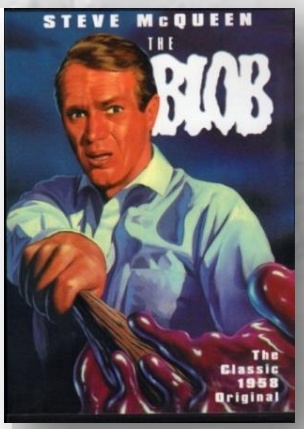


We Knew Jack Would be Back

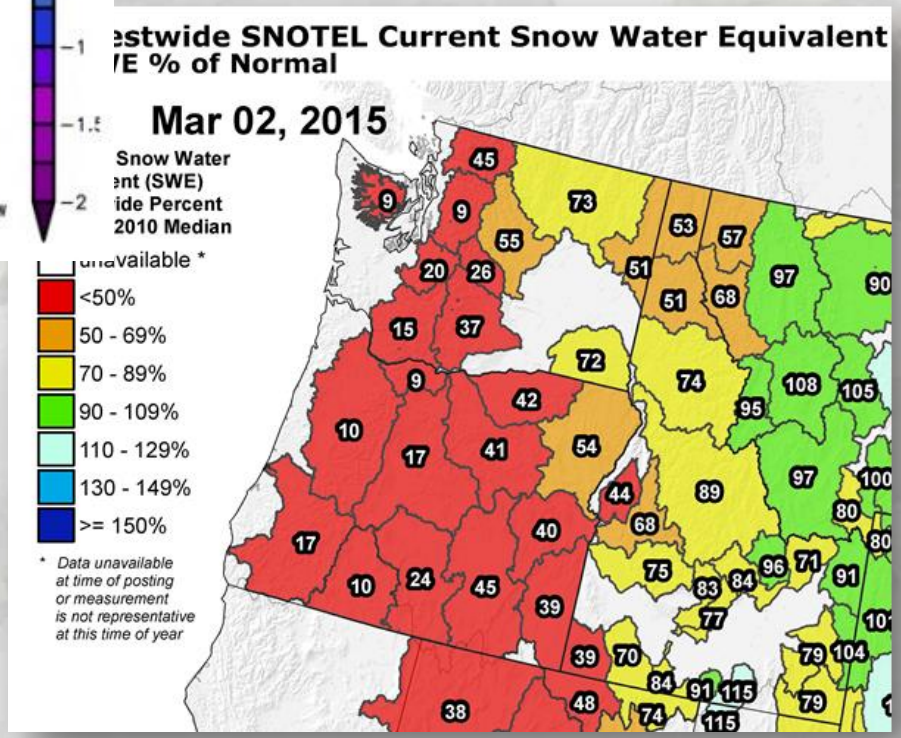


The Blob Ate This Year's Snow



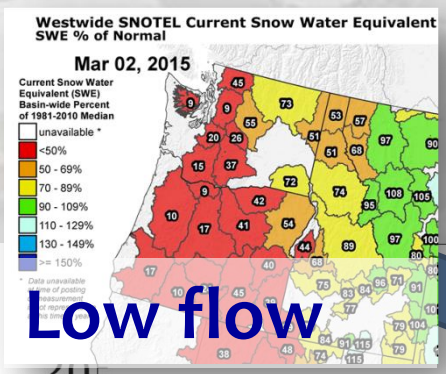


Record Low Snow…



New Stream Temperature Records This Year

NFK Clearwater River North Idaho (1970-2015)



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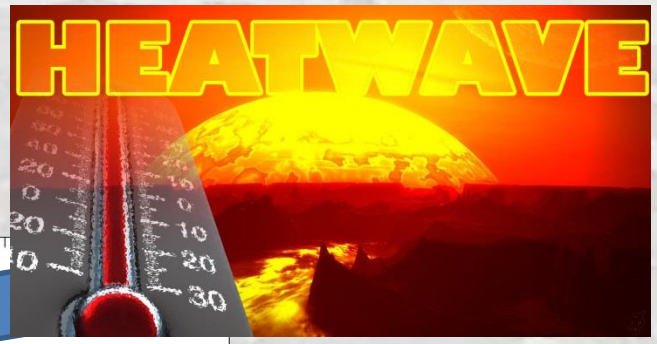
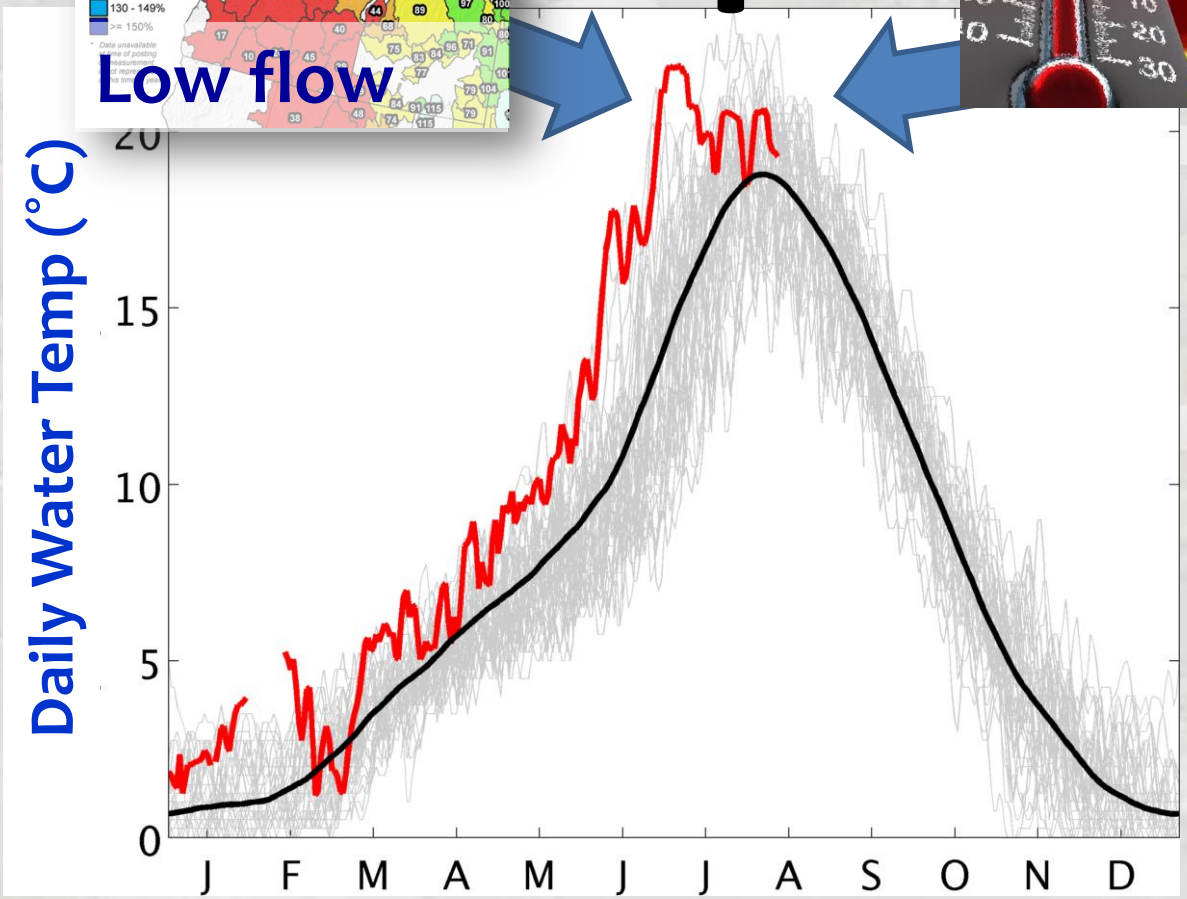
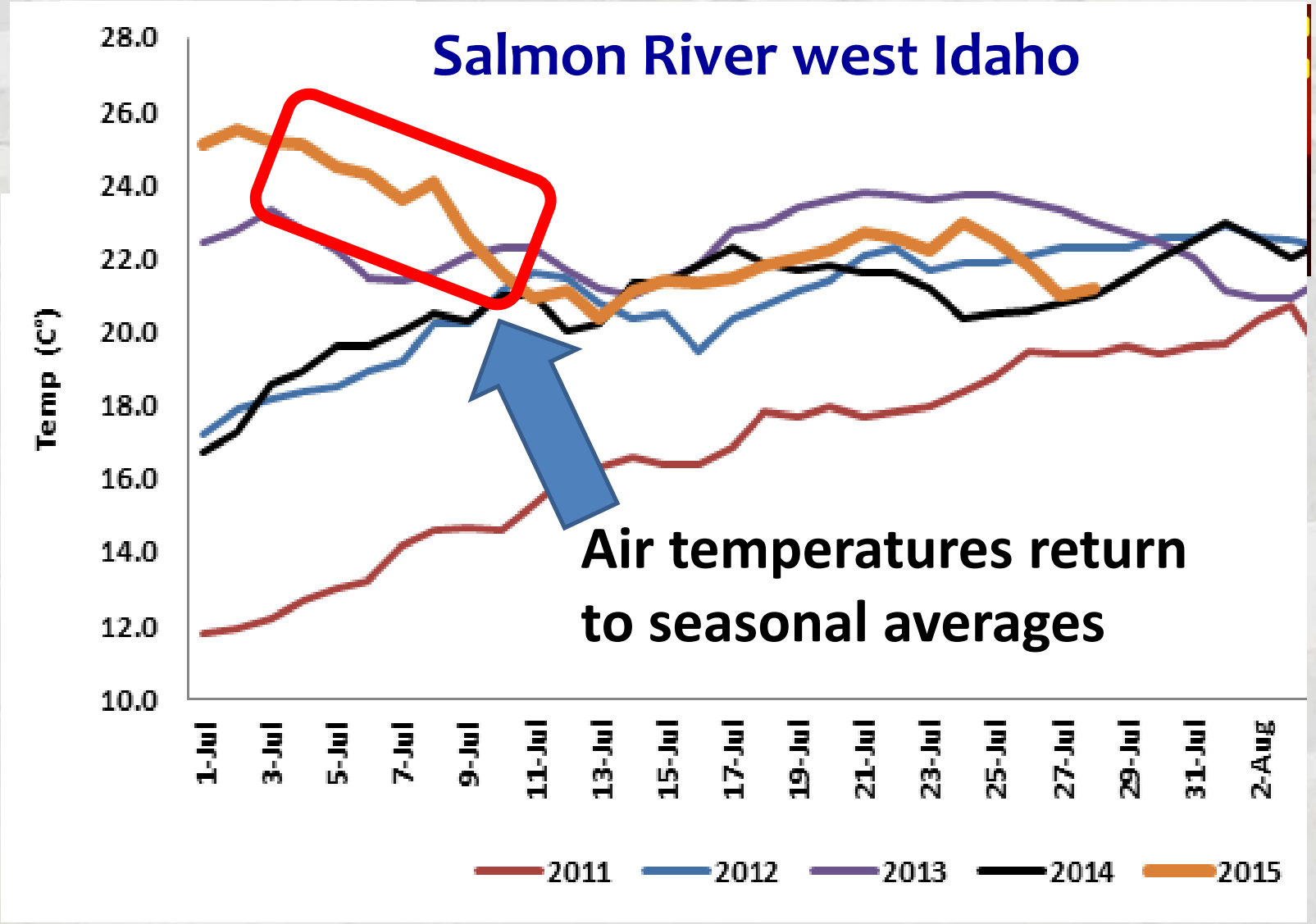




New Stream Temperature Records This Year



A Lot of Fish Came Back

Crowding creates additional stress around fish ladders & spawning grounds

Summer Chinook Return Forecasted To Be Largest Since 1961; Gillnetters Raise Catch Allocation Issues

Posted on Friday, July 10, 2015 (PST)

The summer chinook salmon run forecast was increased to an estimated 100,000 fish Mon
Advisory Committee -- the la
More...

Summer Chinook, Steelhead, Sockeye Fishing Begins Next Week; Strong Sockeye Return Forecasted

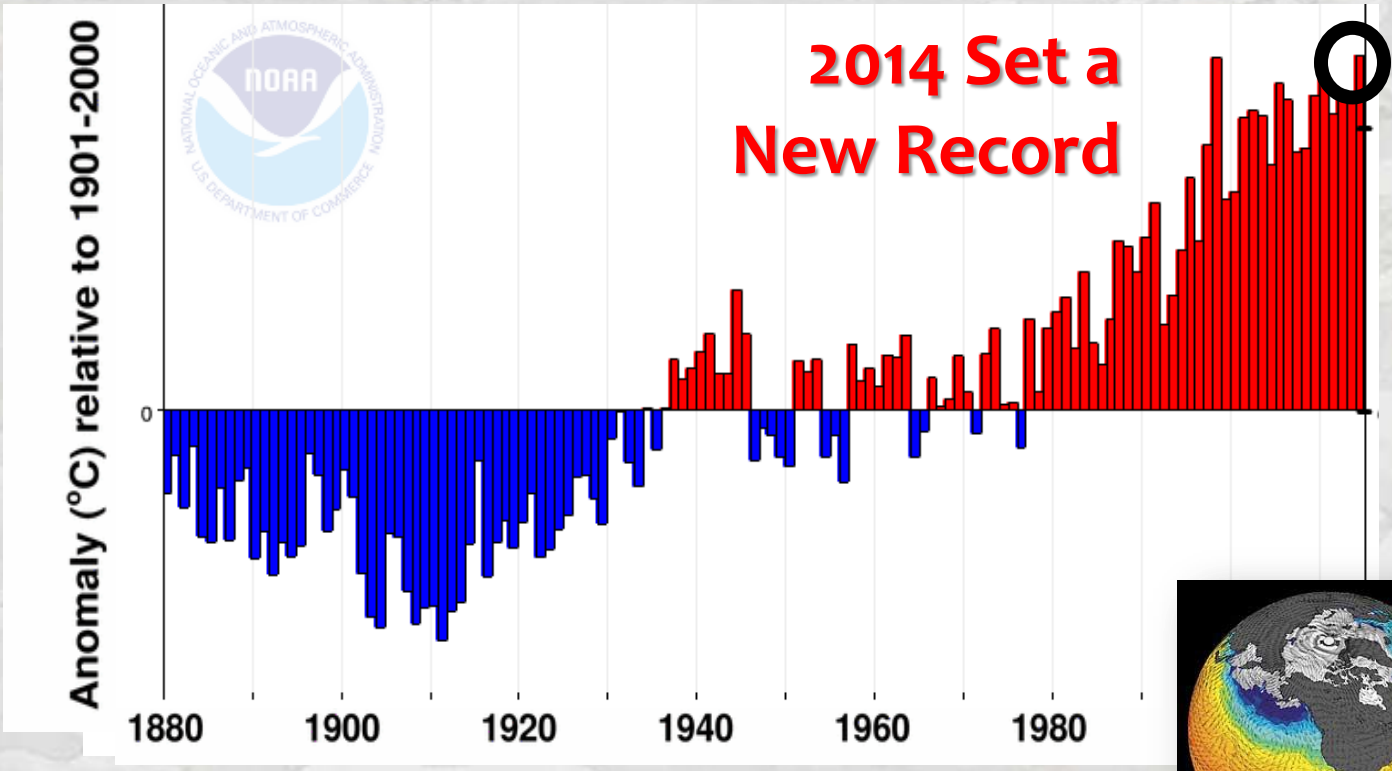
Posted on Friday, June 12, 2015 (PST)

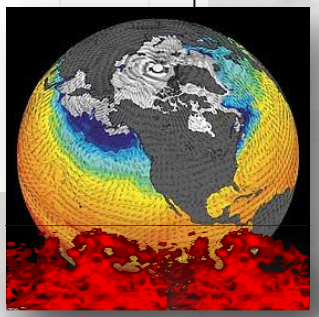
With the spring chinook salmon run estimate rising above 282,000 fish, the two-state Columbia River Compact added more fishing time for both commercial and treaty Indian gillnett
remains open in all zones on the Col
. Read More...

2015 is a "Perfect storm"

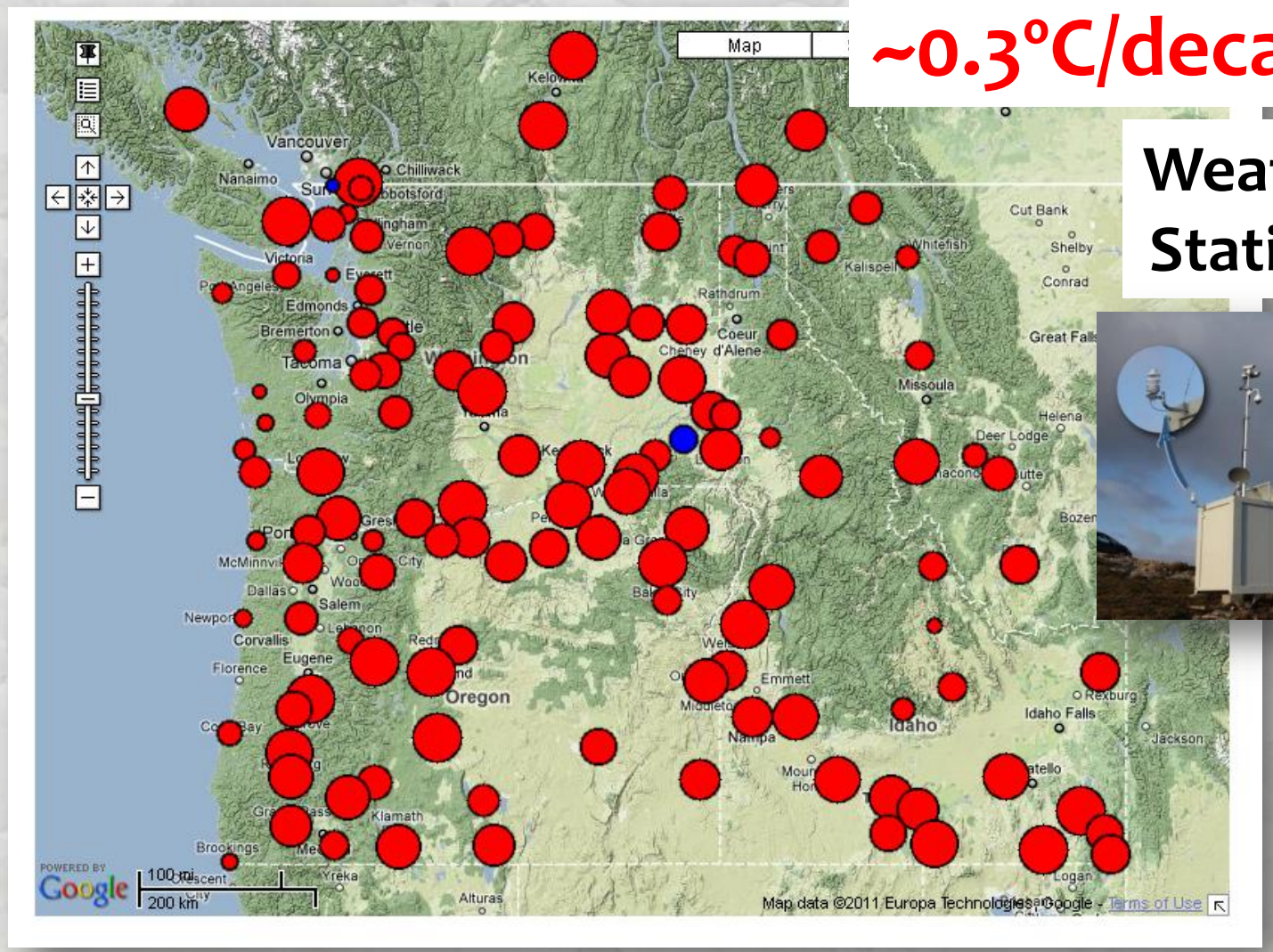
The Odds are Tilting Towards More "Perfect Storms" in the Future

1880-2014 Global Air Temperature Trend





PNW Summer Air Trends (1980–2013)



~0.3°C/decade

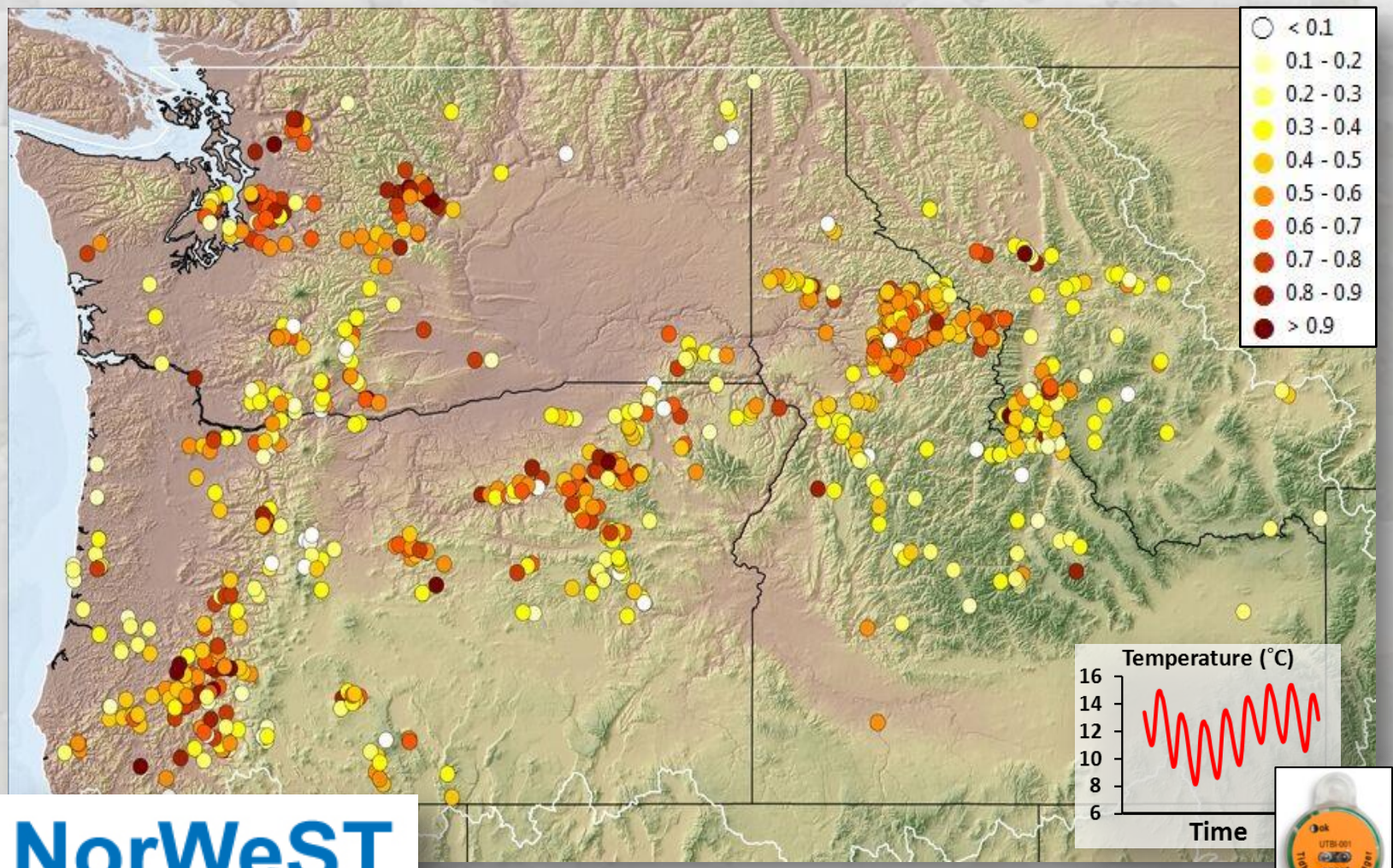
Weather Stations

OWSC Climate Tool map

http://www.climate.washington.edu/trendanalysis/

Stream Response to Air Temperatures

923 sites in NorWeST database with 10-20 year records

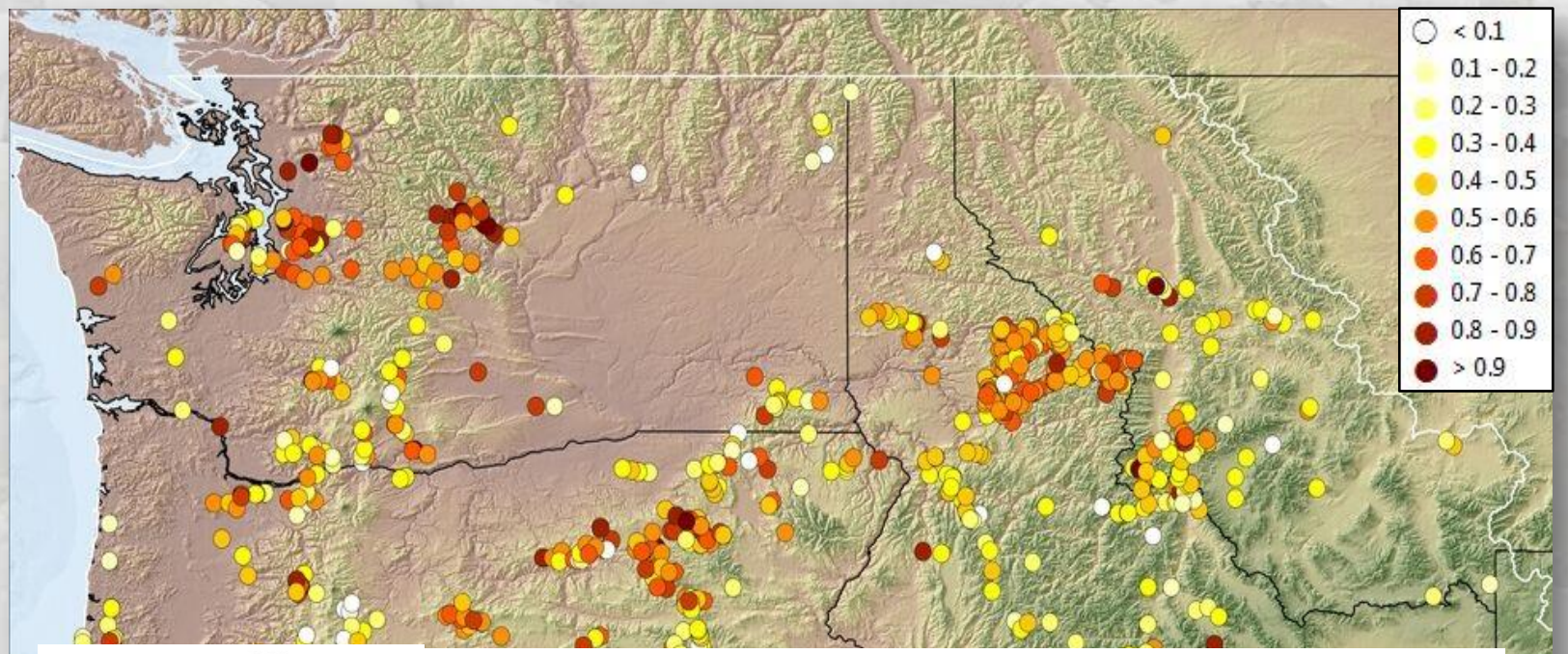


NorWeST Stream Temp

Isaak et al. In Preparation

Stream Response to Air Temperatures

923 sites in NorWeST database with 10-20 year records

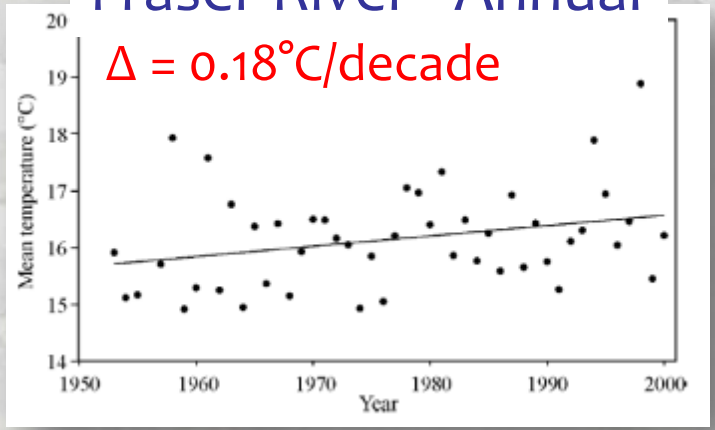


Streams warming ~50% as fast as air temperatures (~0.15°C/decade)

Isaak et al. In Preparation

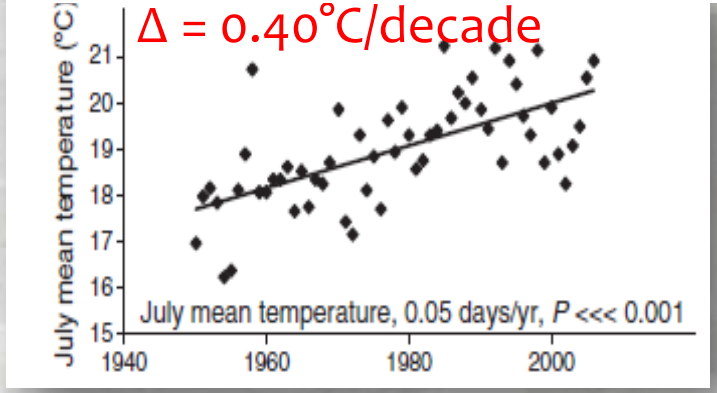
But Big Rivers are Warming Faster…

Fraser River - Annual



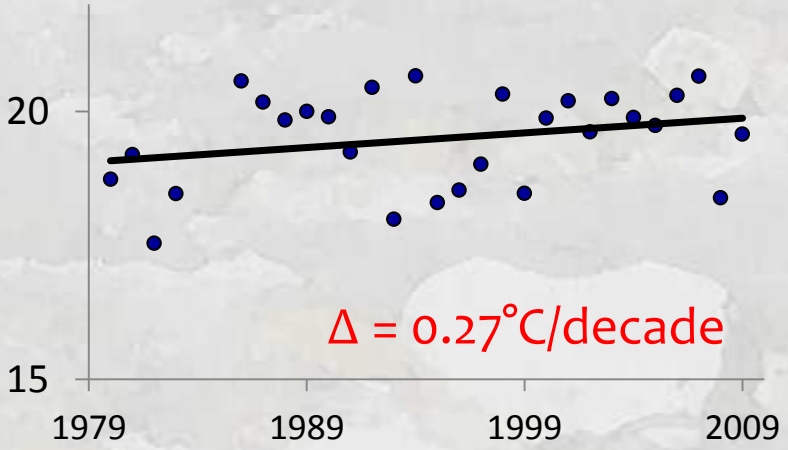
Morrison et al. 2001

Columbia River - Summer

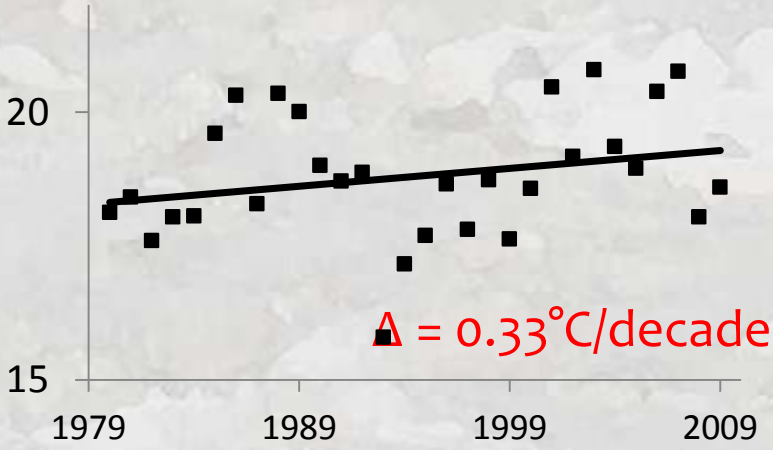


Crozier et al. 2008

Snake River, ID - Summer



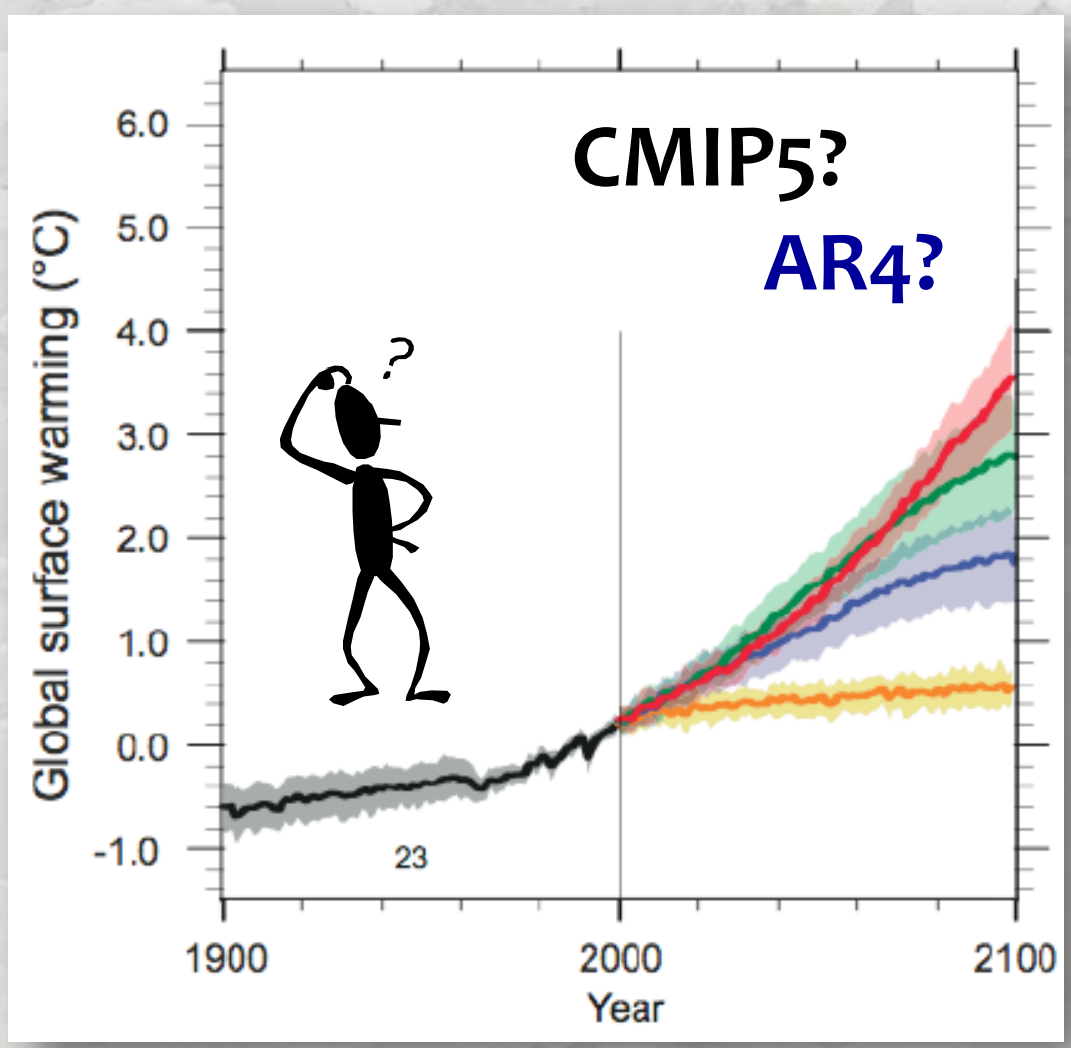
Missouri River, MT - Summer



Isaak et al. 2012. *Climatic Change* **113**:499-524.

How Much Warmer & When?

The Future is Uncertain…

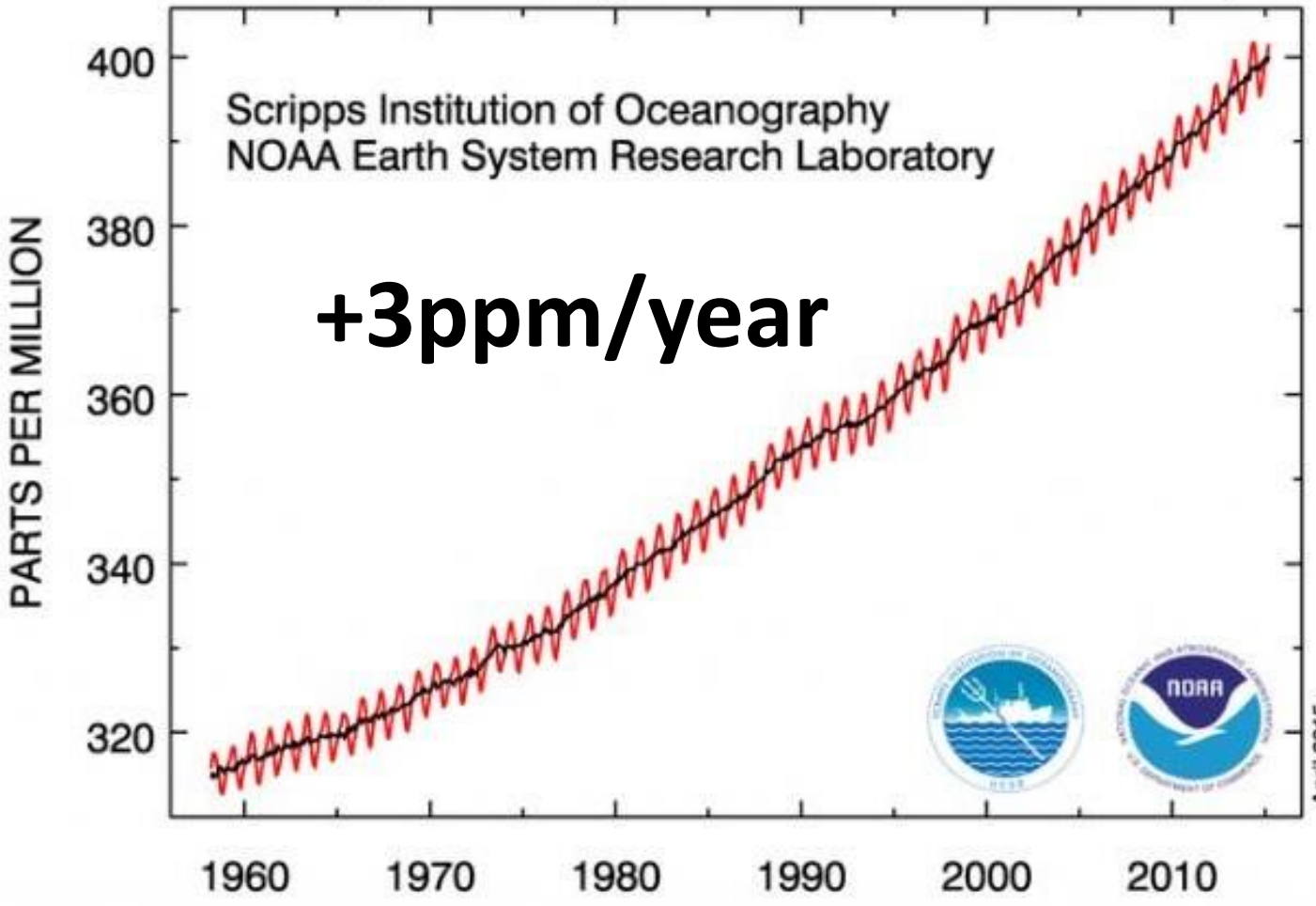


The Specifics are an "Unknowable Unknown"

… except that it will keep getting warmer

How Much Warmer & When?

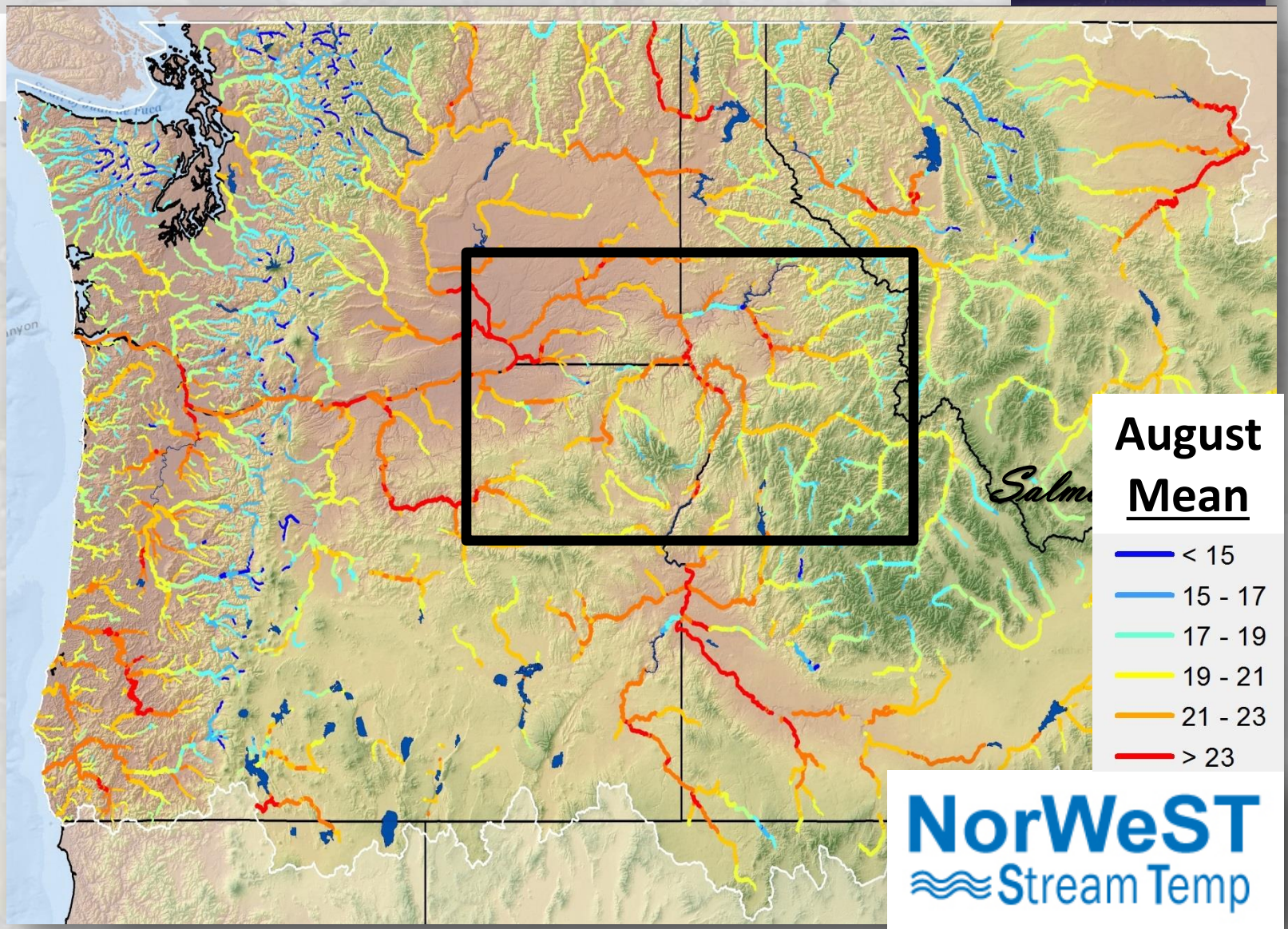
Atmospheric CO2 Concentration



s are
vable
"

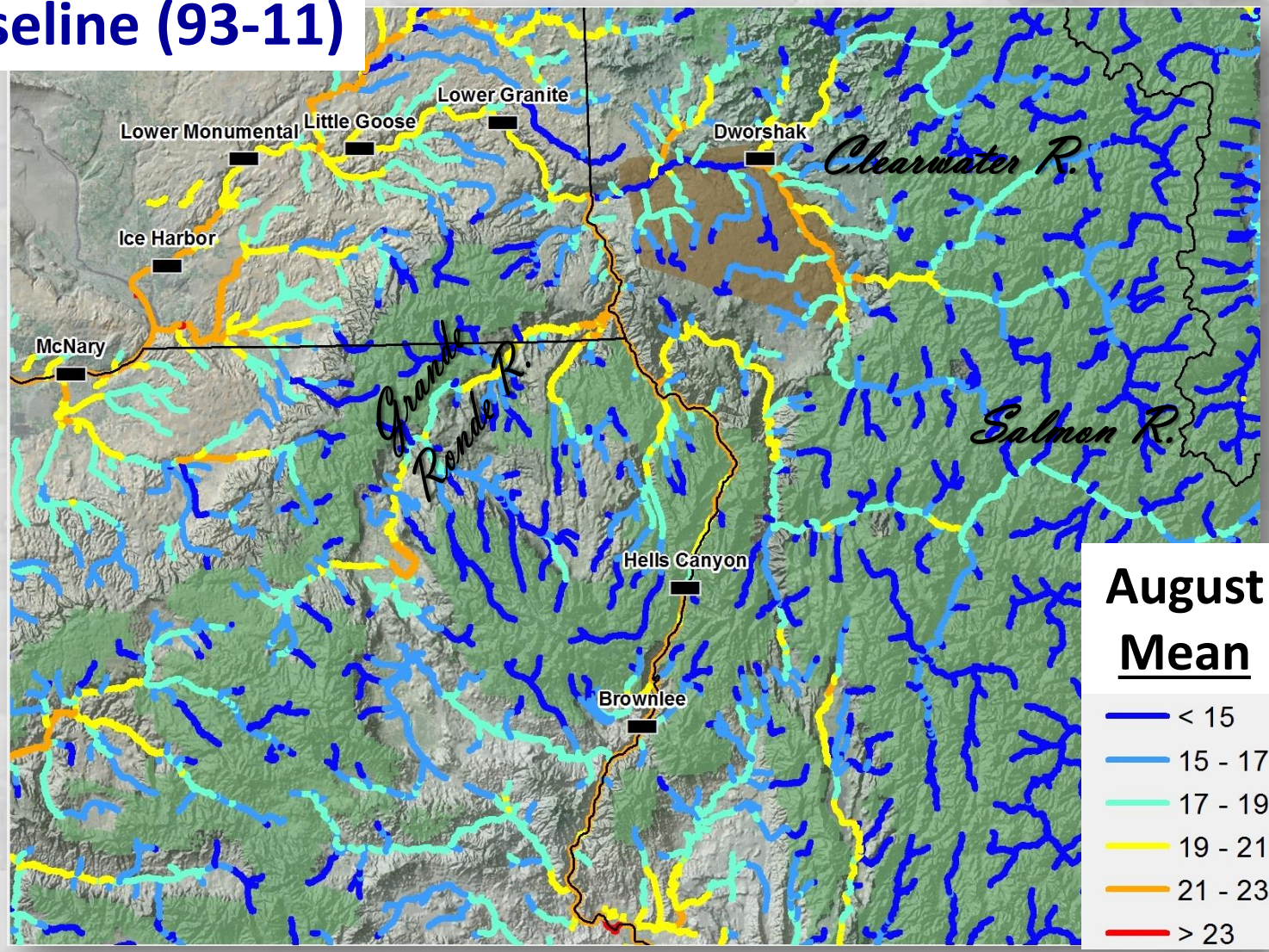
… except that it will keep getting warmer

What Are Predictions for Salmon Rivers?



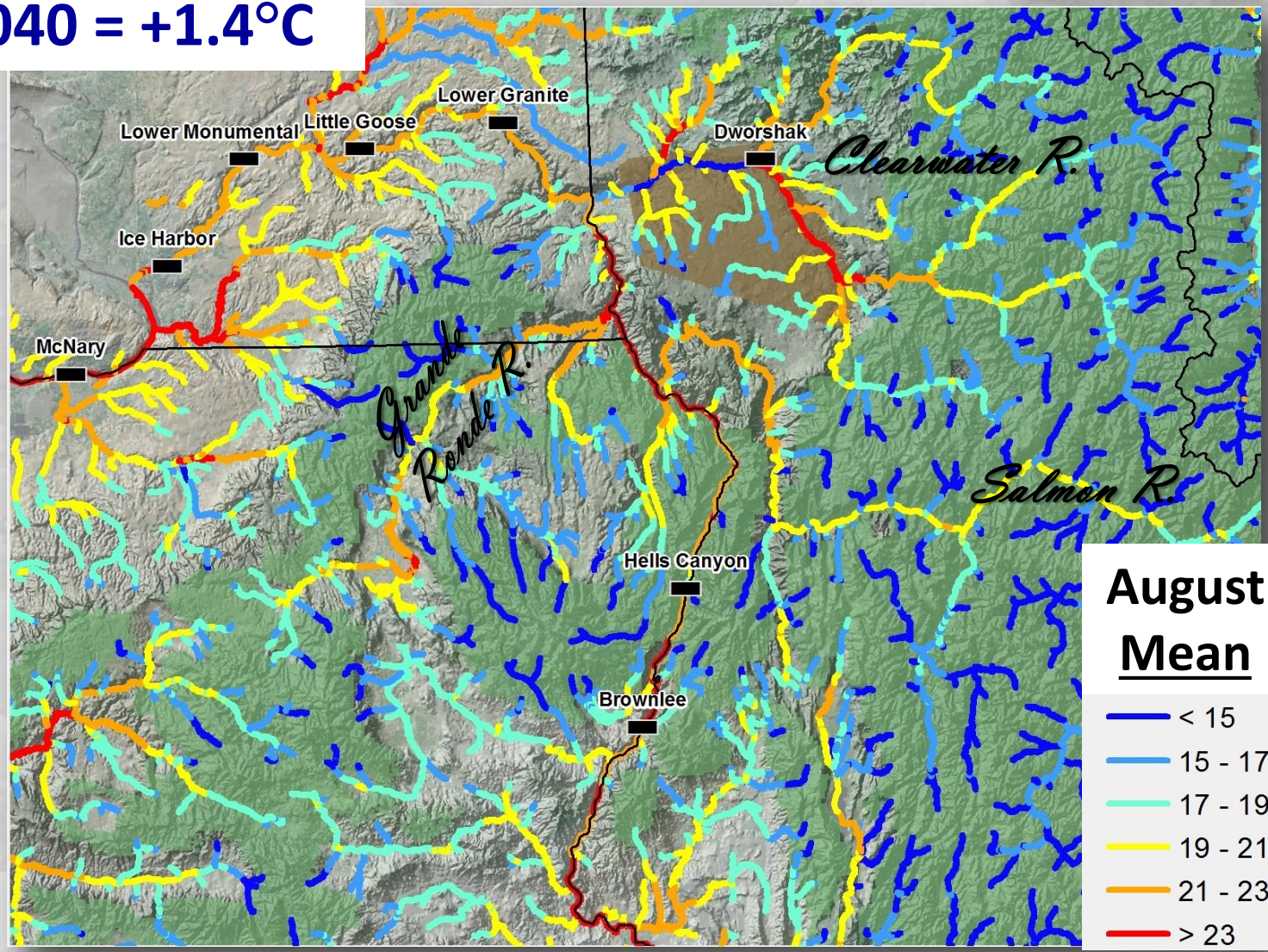
What Are Predictions for Salmon Rivers?

Baseline (93-11)



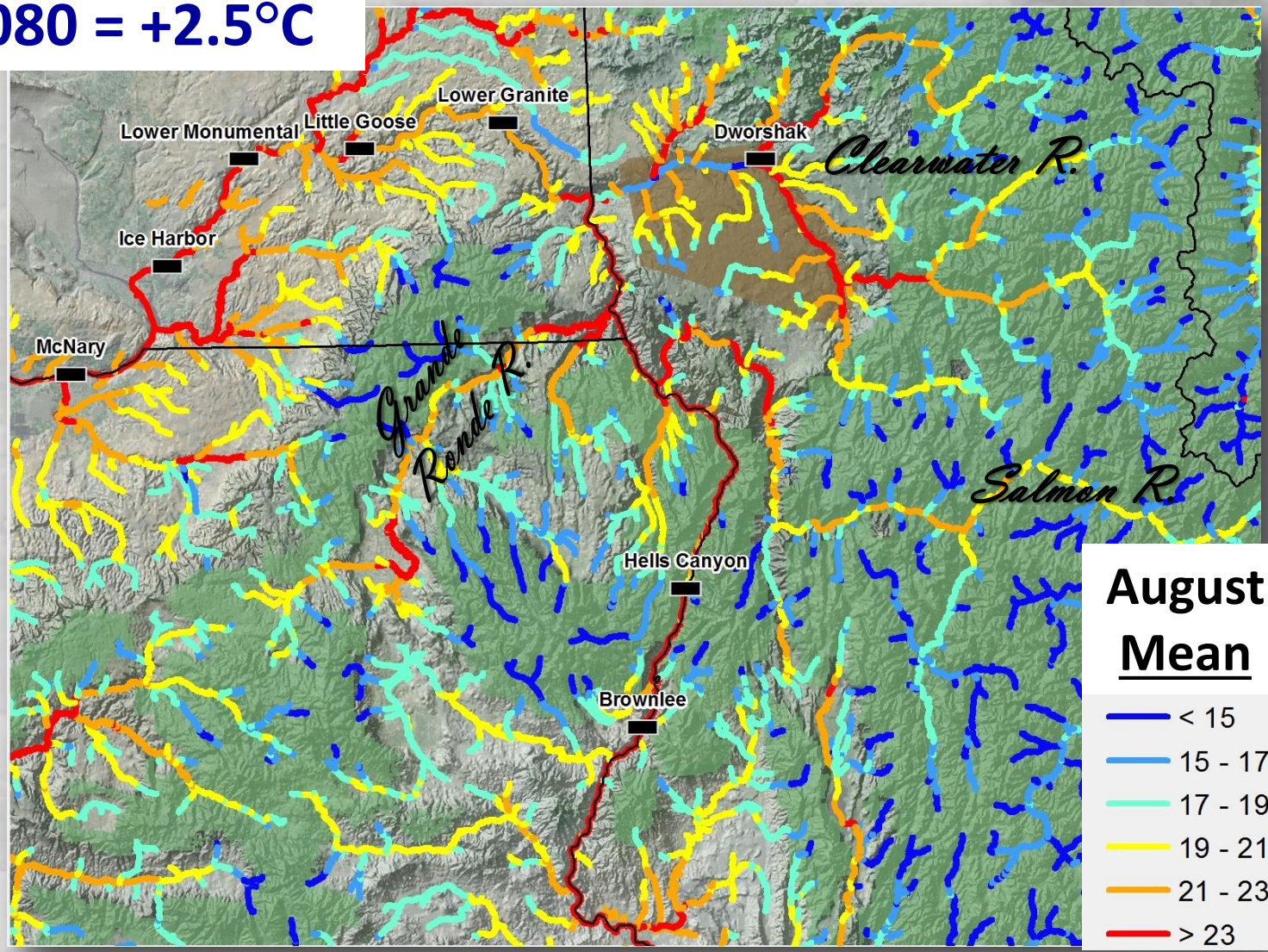
What Are Predictions for Salmon Rivers?

2040 = +1.4°C



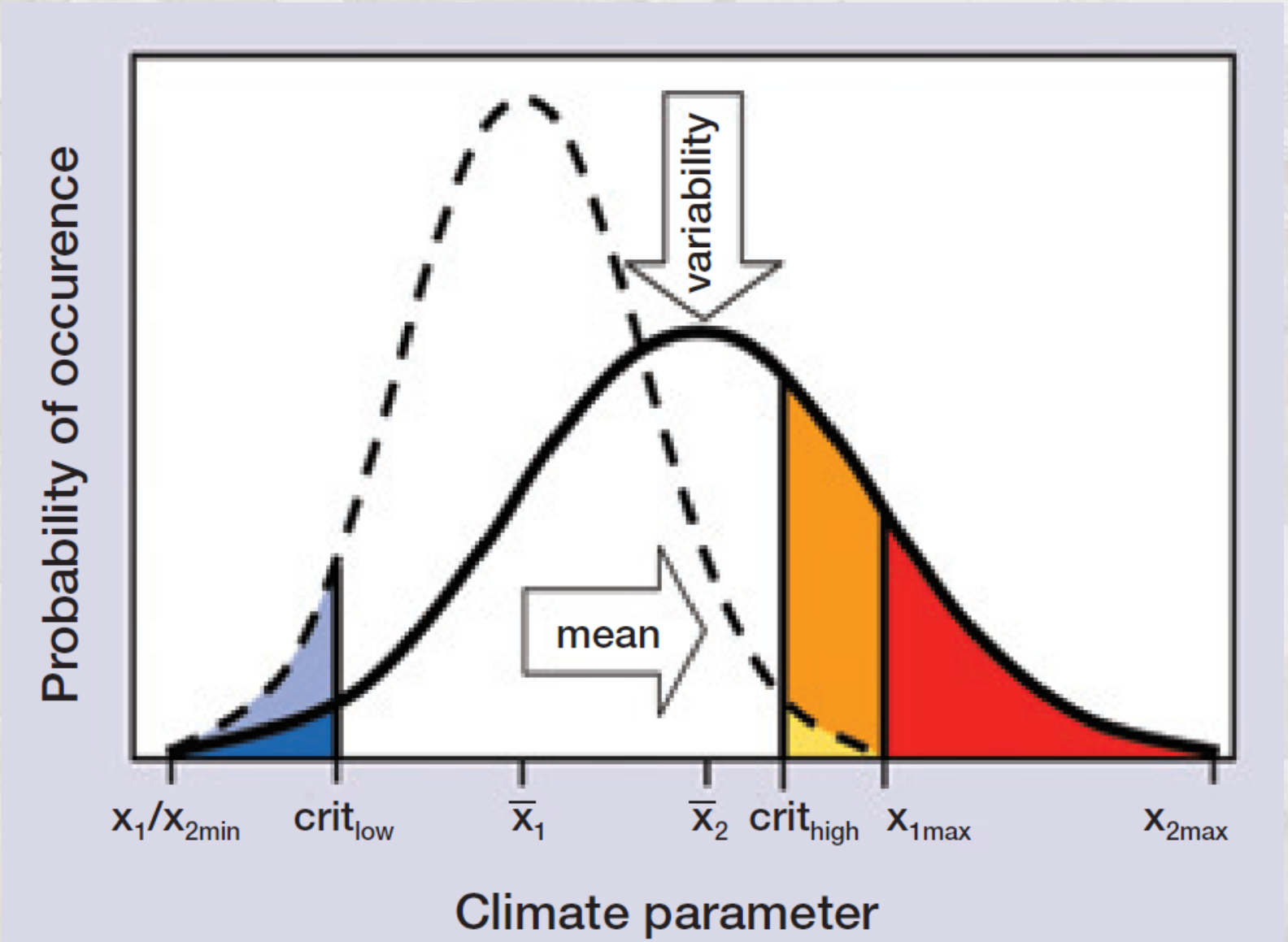
What Are Predictions for Salmon Rivers?

2080 = +2.5°C



Short-Term Maxima Change Faster than Means

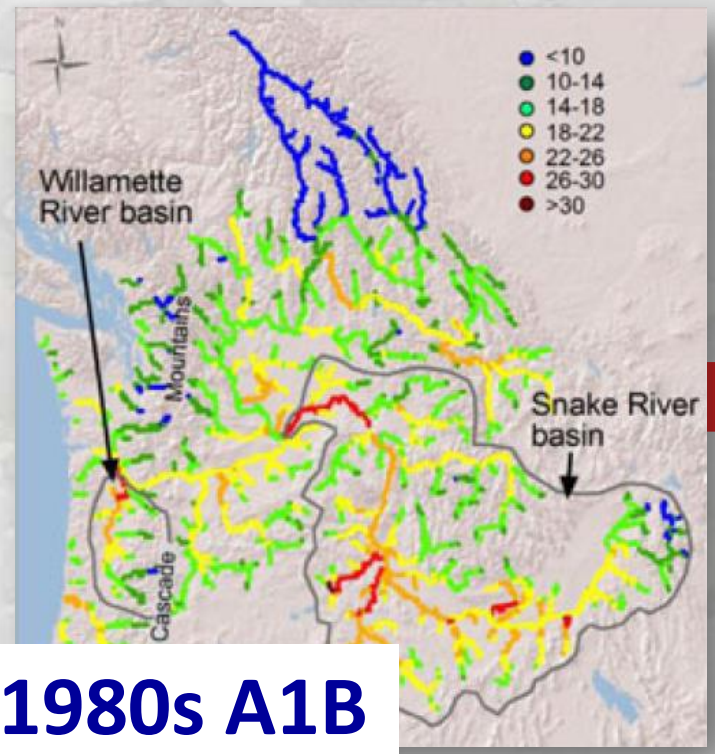
"Extreme" conditions happen more frequently



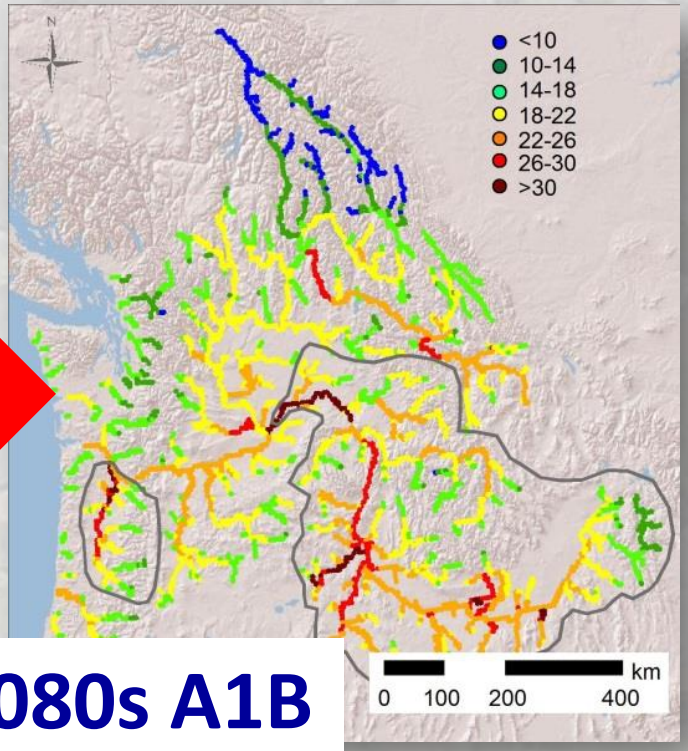
Future Maximum Weekly Maximum Temps

Mainstem River Increases: 2040s ~ +2.5°C

2080s ~ +4.0°C



1980s A1B

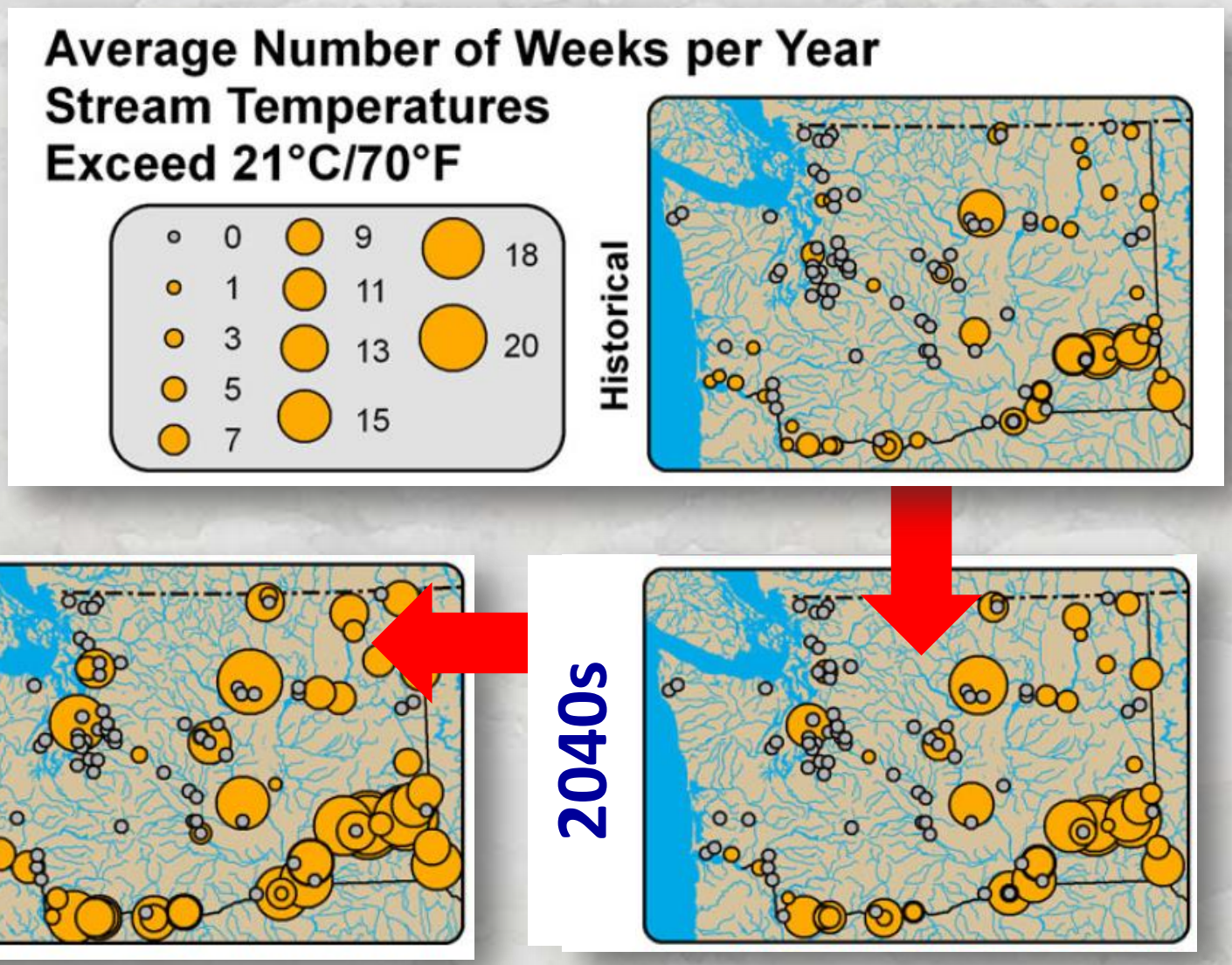


2080s A1B

Wu et al. 2012. Projected climate change impacts on the hydrology and temperature of Pacific Northwest rivers. *Water Resources Research* **48**, W11530, doi:10.1029/2012WR012082

Beechie et al. 2013. Restoring salmon habitat for a changing climate. *River Research and Applications* **29**:939-960.

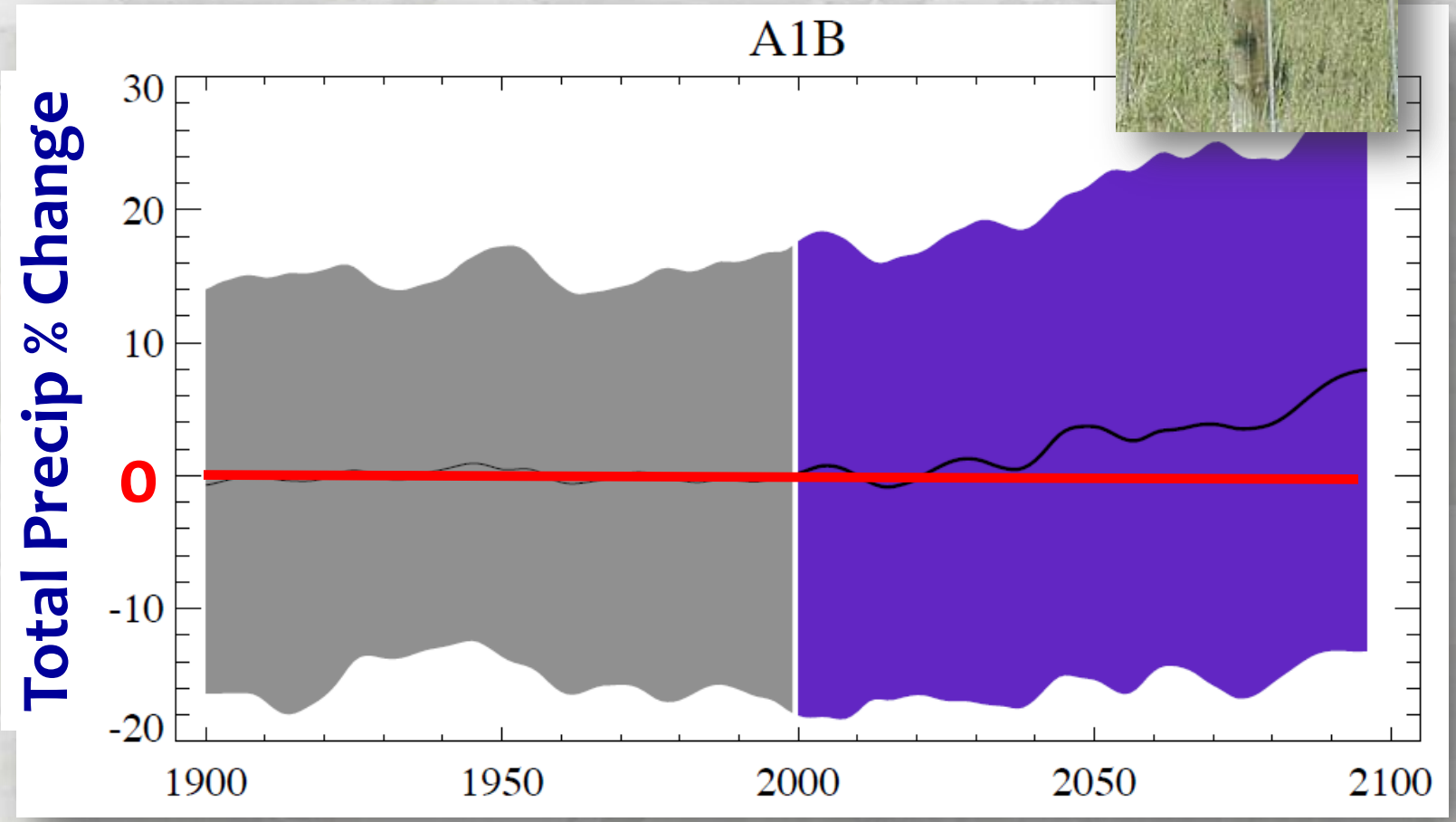
Annual Duration of High Temperatures



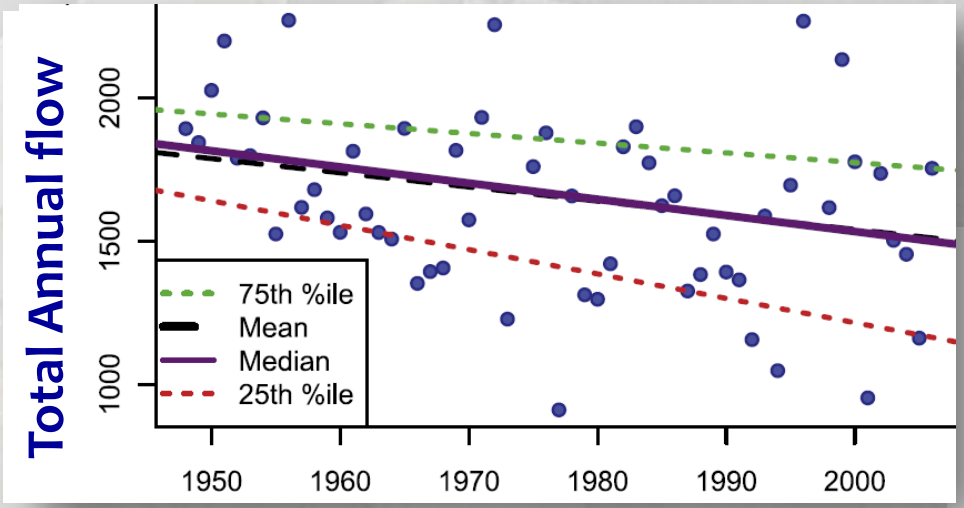
Mantua et al. 2010. *Climatic Change* **102**:187-223.

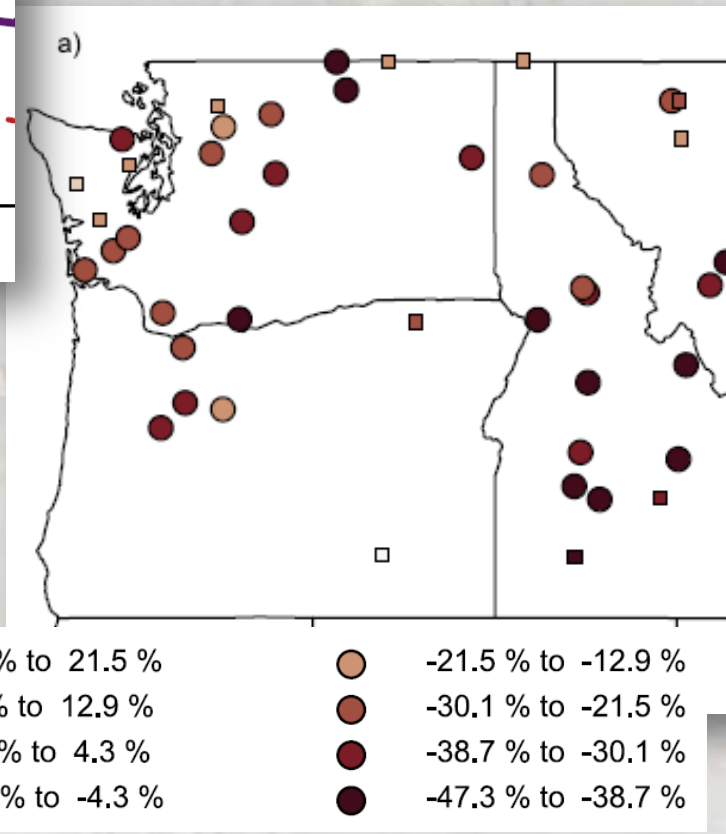
A Wetter or Drier Future?

Predictions are less certain



…but total Annual Flows & Low Flows Have Been Decreasing (1948-2006)

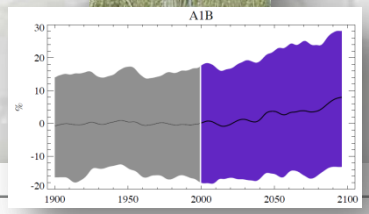




(Luce and Holden 2009)

Decreasing Wind Speeds & Total Precipitation at High Elevations

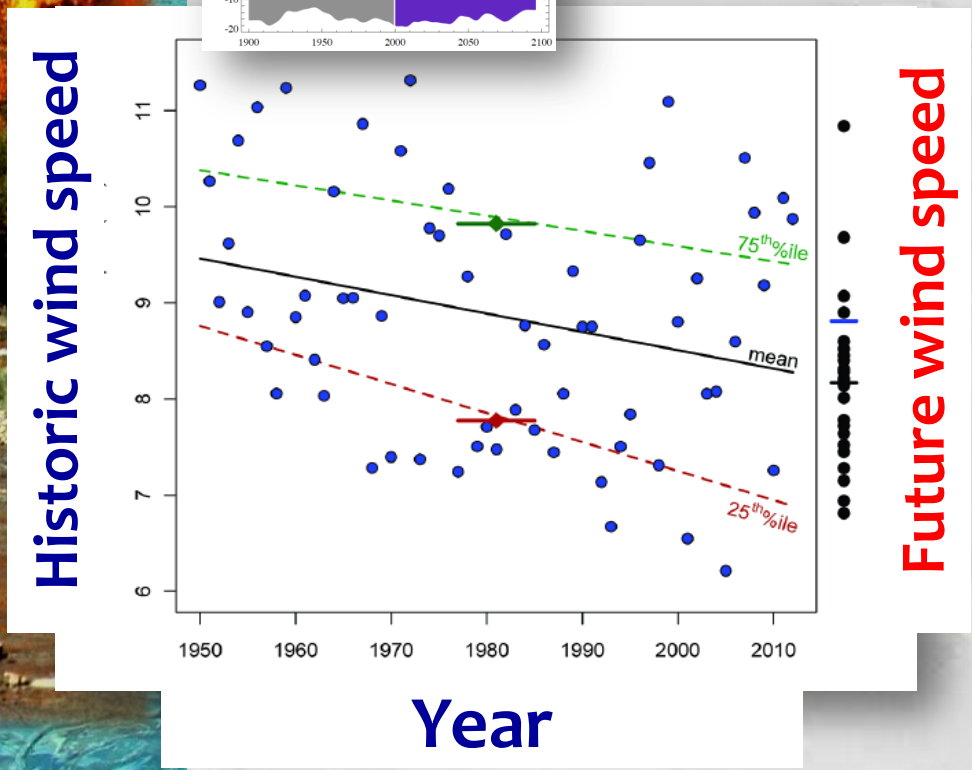
≠

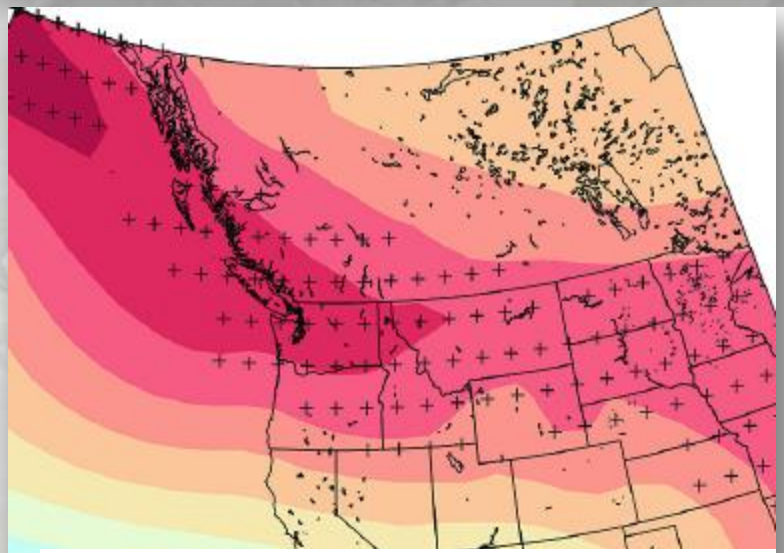


Sciencexpress

The Missing Mountain Water: Slower Westerlies Decrease Orographic Enhancement in the Pacific Northwest

C. H. Luce,[1]* J. T. Abatzoglou,[2] Z. A. Holden[3]

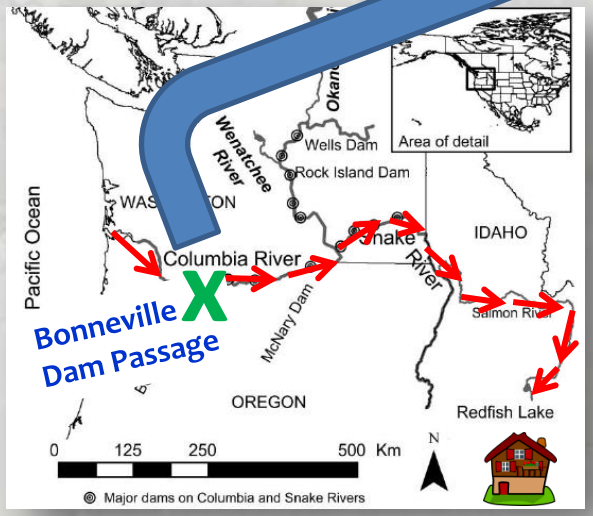


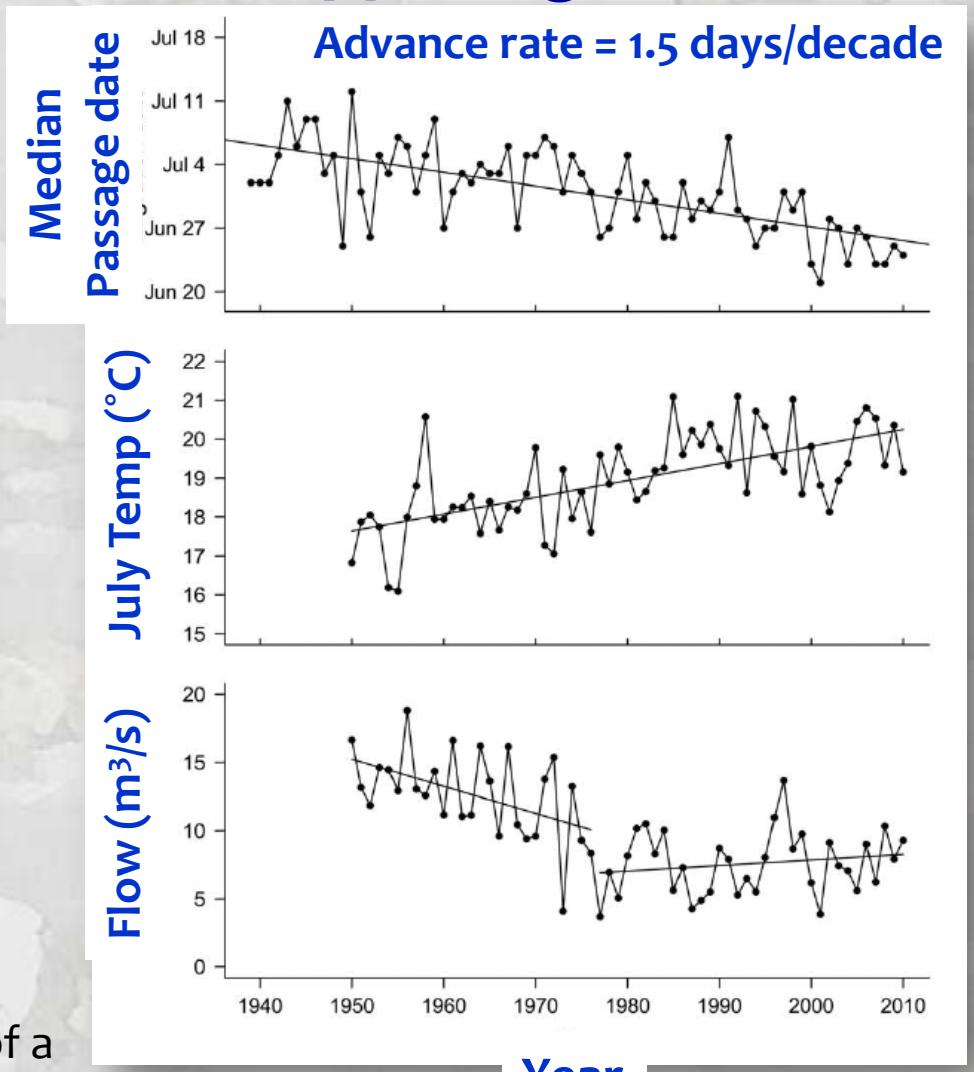


CMIP5 Wind Projections (2070-2100)

Fish are Trying to Follow Climate

Sockeye Migrations Happening Earlier…



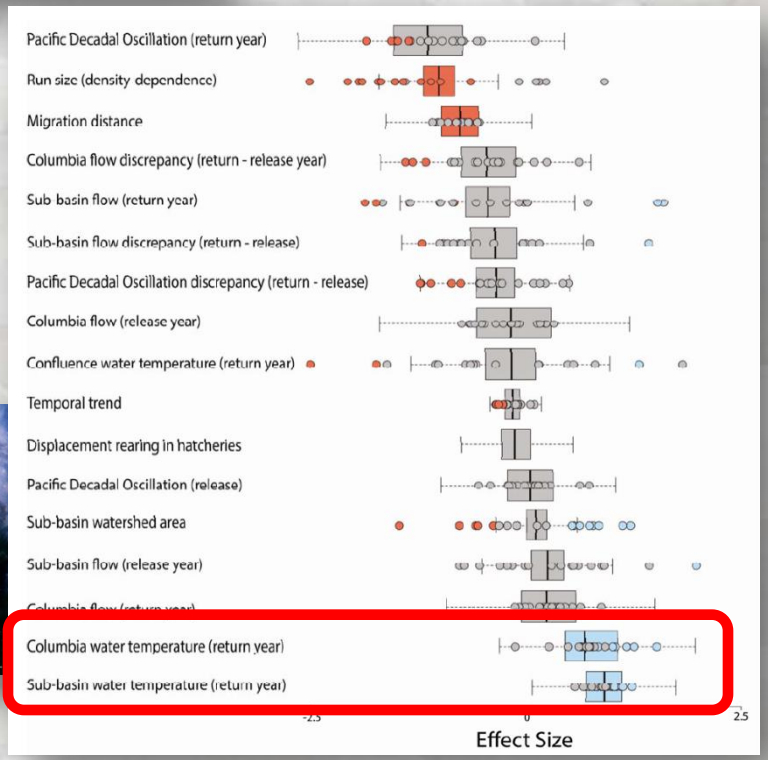


Crozier et al. 2011. A Case Study of a Shift toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* **178**:755-773.

NorWeST Temperature & Salmon Hatchery Straying Rates

1993-2011

Environmental Predictors



E.T. Go Home

Not in Hot Years

Westley et al. 2015. Signals of climate, conspecific density, and watershed features in patterns of Pacific salmon straying. ***Ecology*** doi.org/10.1890/14-1630.1

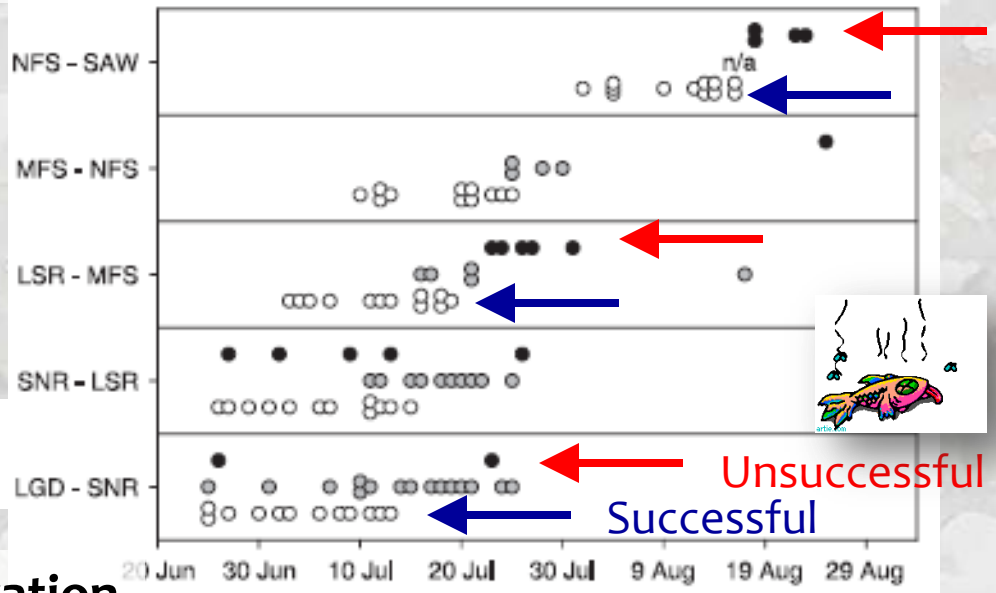
…Can They Stay Ahead of Changes?

Later Sockeye Return Less Successfully

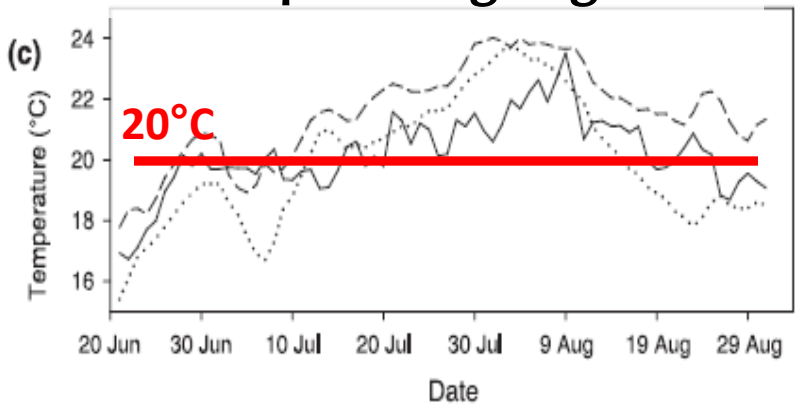
Natal Areas

Snake River

Migration Success vs. Timing



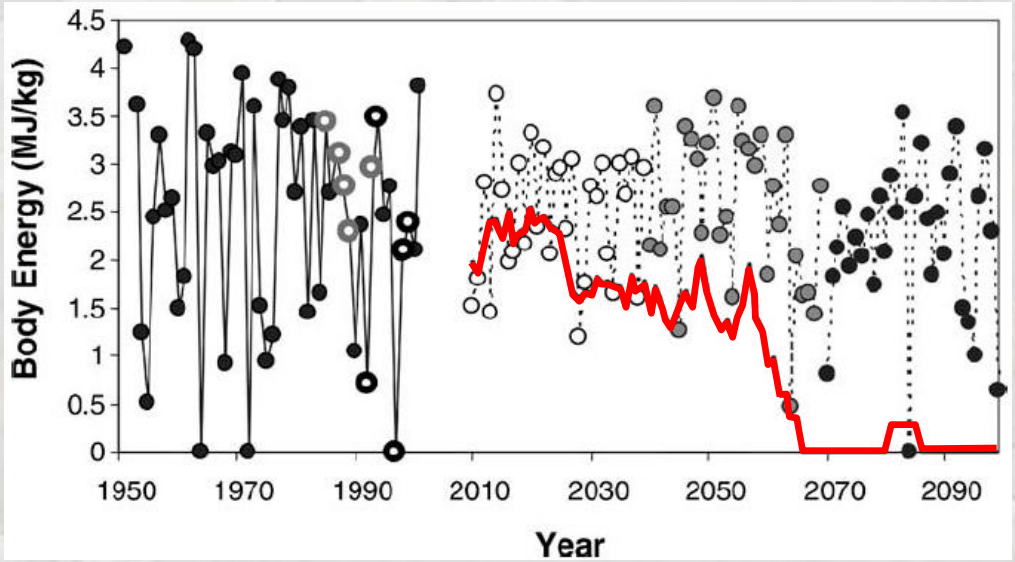
Stream Temps During Migration

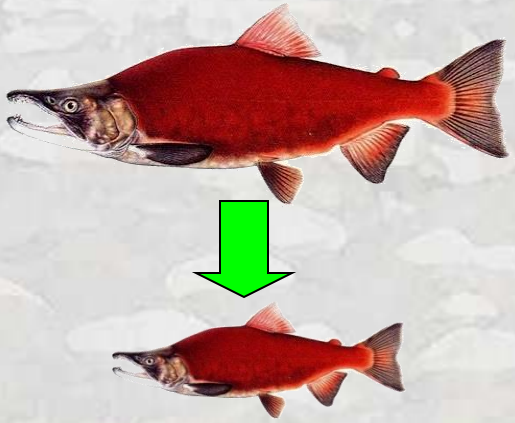


Keefer et al. 2008. *Ecology of Freshwater Fish* **17**:136-145

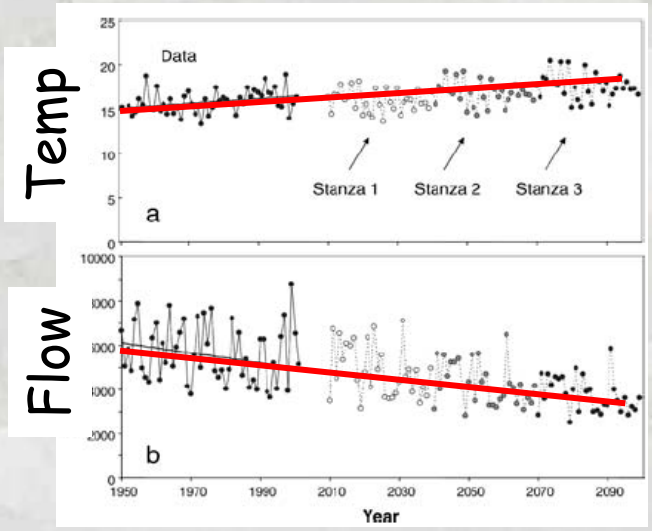
… Earlier fish are Smaller Fish

Fraser River Sockeye Bioenergetics Model



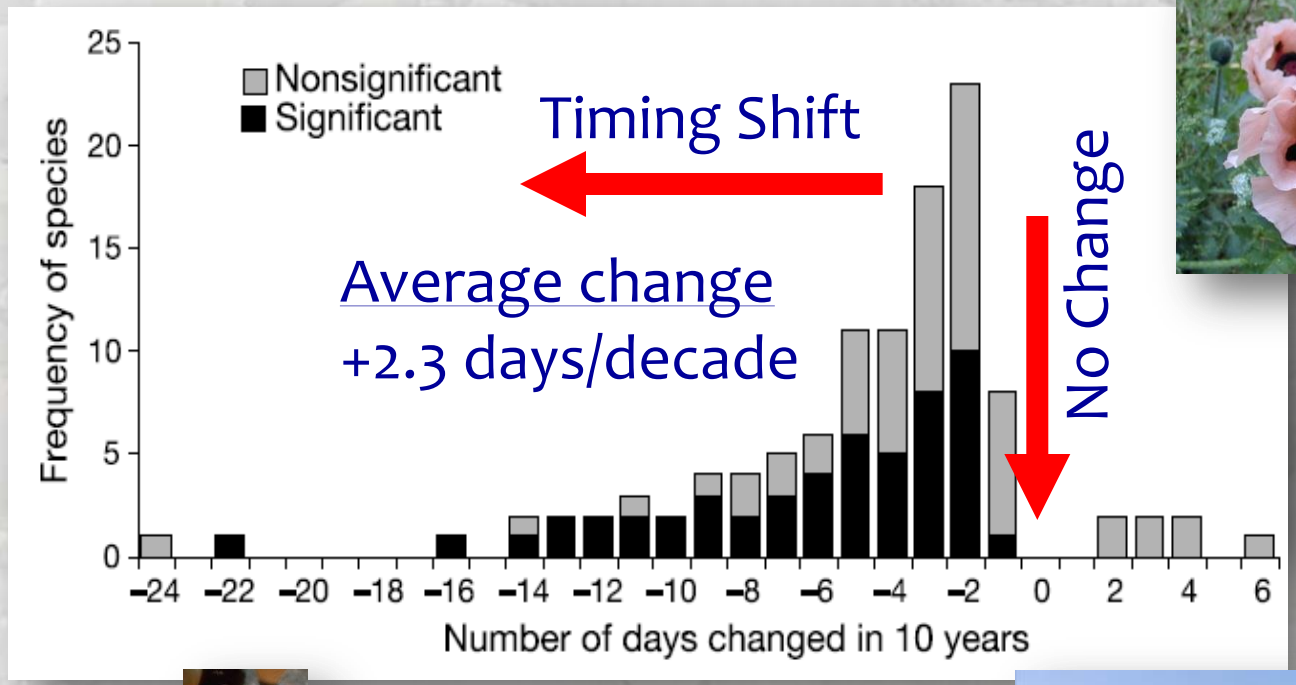


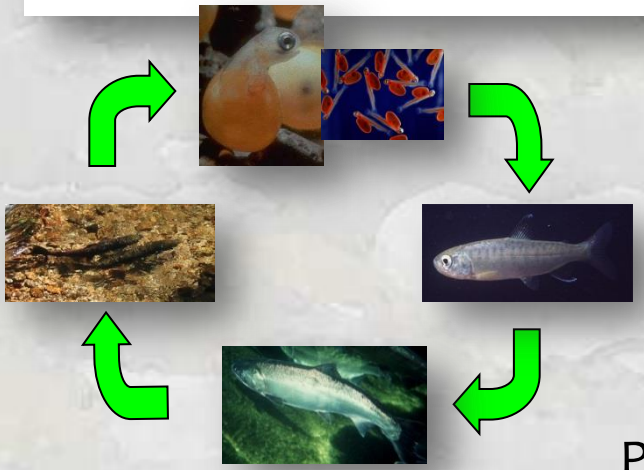
Fraser River Trends in…



Rand et al. 2006

100s of Studies Show Similar Phenology Trends in a Wide Array of Taxa





Parmesan and Yohe. 2003. *Nature* 421:37-42.

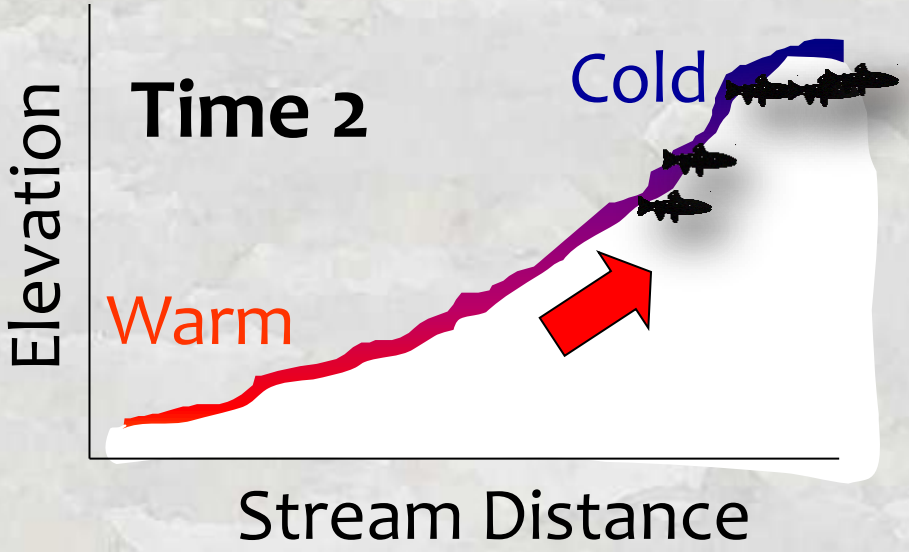
Critter's Distributions Shifting Towards Cooler Areas

Average distribution shift

6.1 km/decade poleward

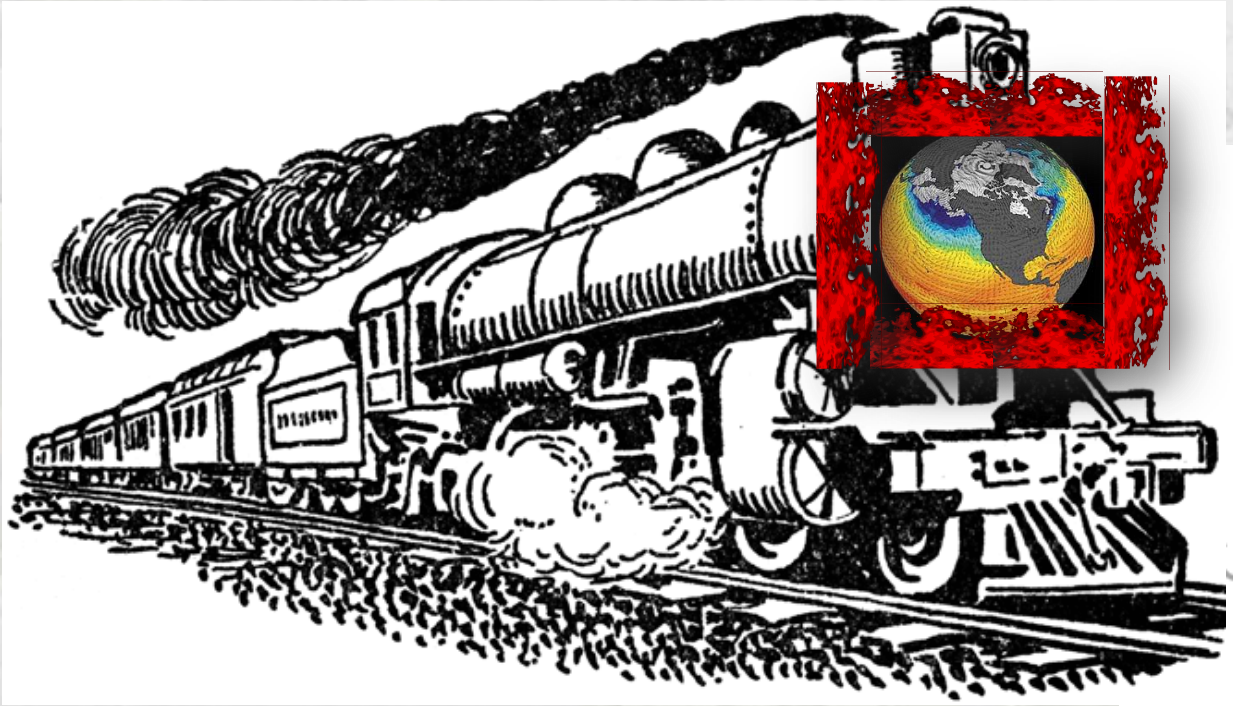
OR

6.1 m/decade higher elevation



Parmesan and Yohe. 2003. *Nature* **421**:37-42.

Move, Adapt, or Die…

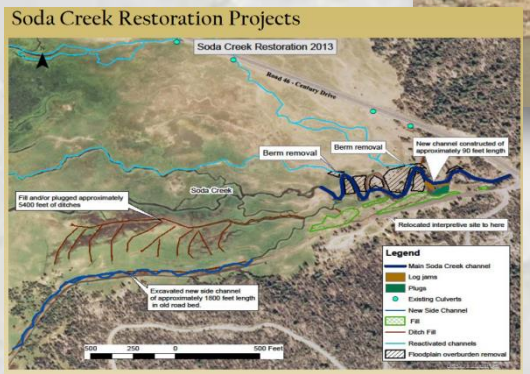


We're Not Stopping The Climate Change Train in the Next 30-40 years

So how to Best Adapt & Lessen the Impact?

Many Things Can be Done to Improve Habitat & Population Resilience

- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Prescribed burns limit wildfire risks…
- Non-native species control…
- Improve/impede fish passage…

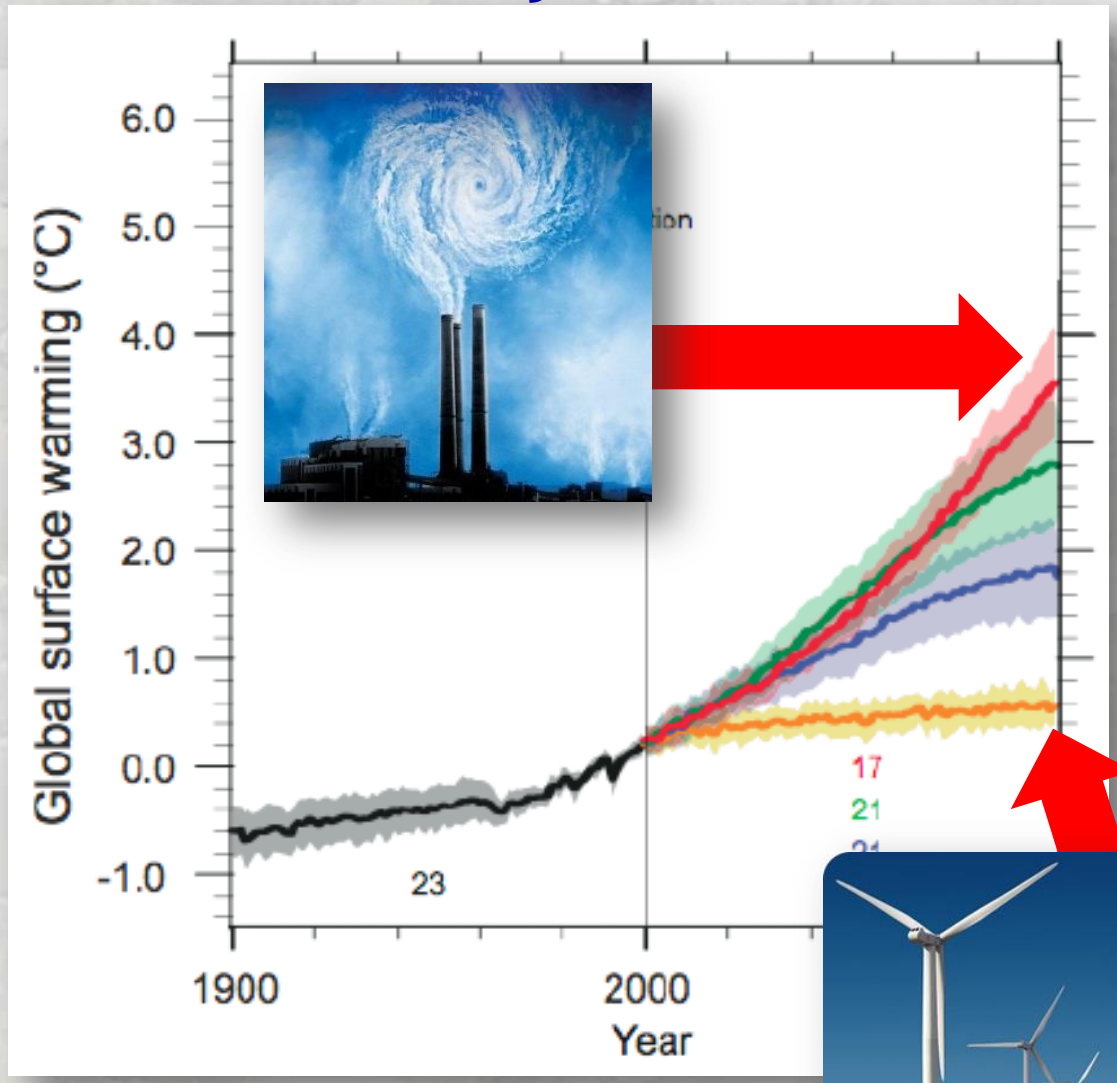


a) Where to do them?

b) Is there a grand strategy?

c) How to maximize bang for the

Great Uncertainty BUT… Current Choices Certainly Set Future Trajectories

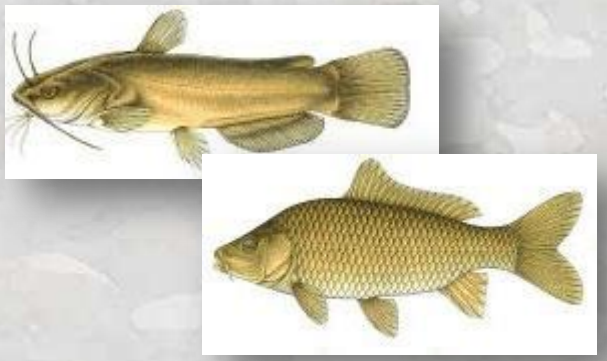


The Specifics are an "Unknowable Unknown"

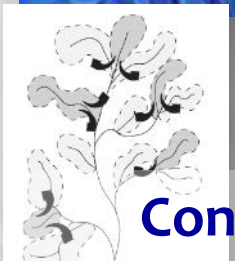
Current Choices Set Future Trajectories

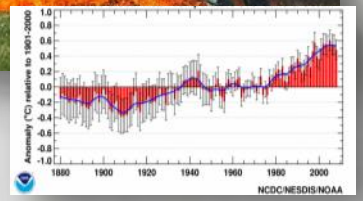
Choice A: Coexistence (do nothing or shape transition to more desirable communities)

OR?



Choice B: Resistance (protect key fisheries & other currently valued resources)

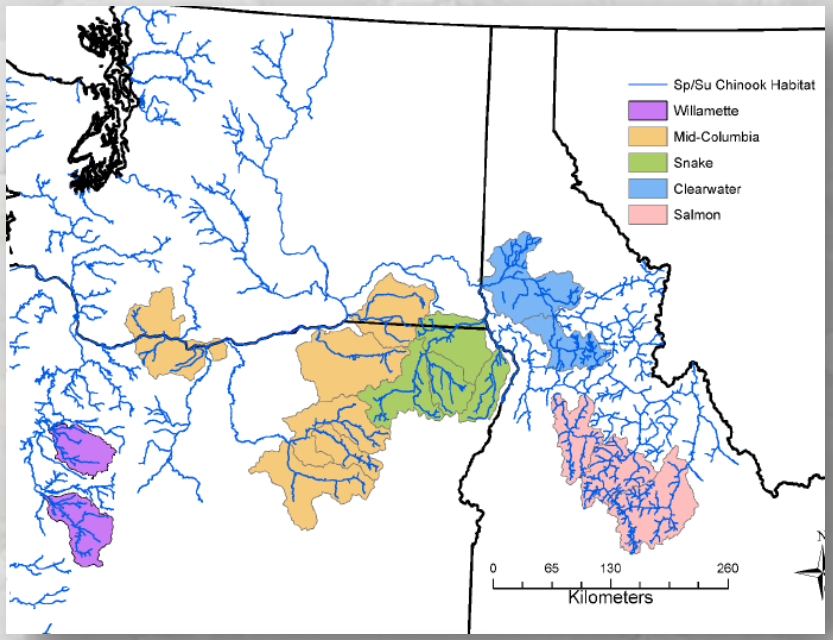


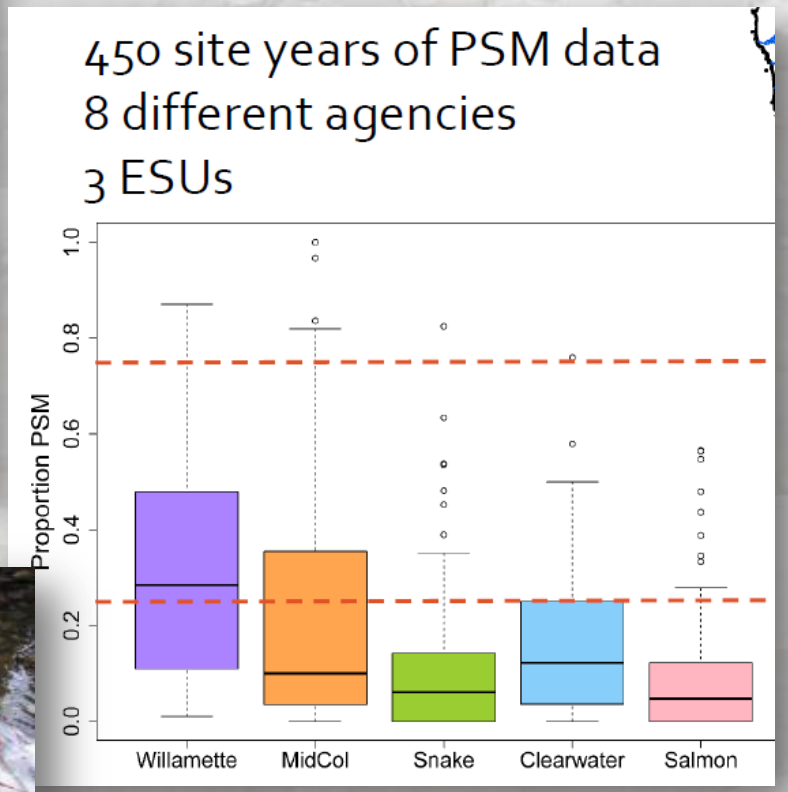


Conservation reserves, important fisheries

Informing Investments with Climate Scenarios

NorWeST & Prespawn Mortality in Salmon

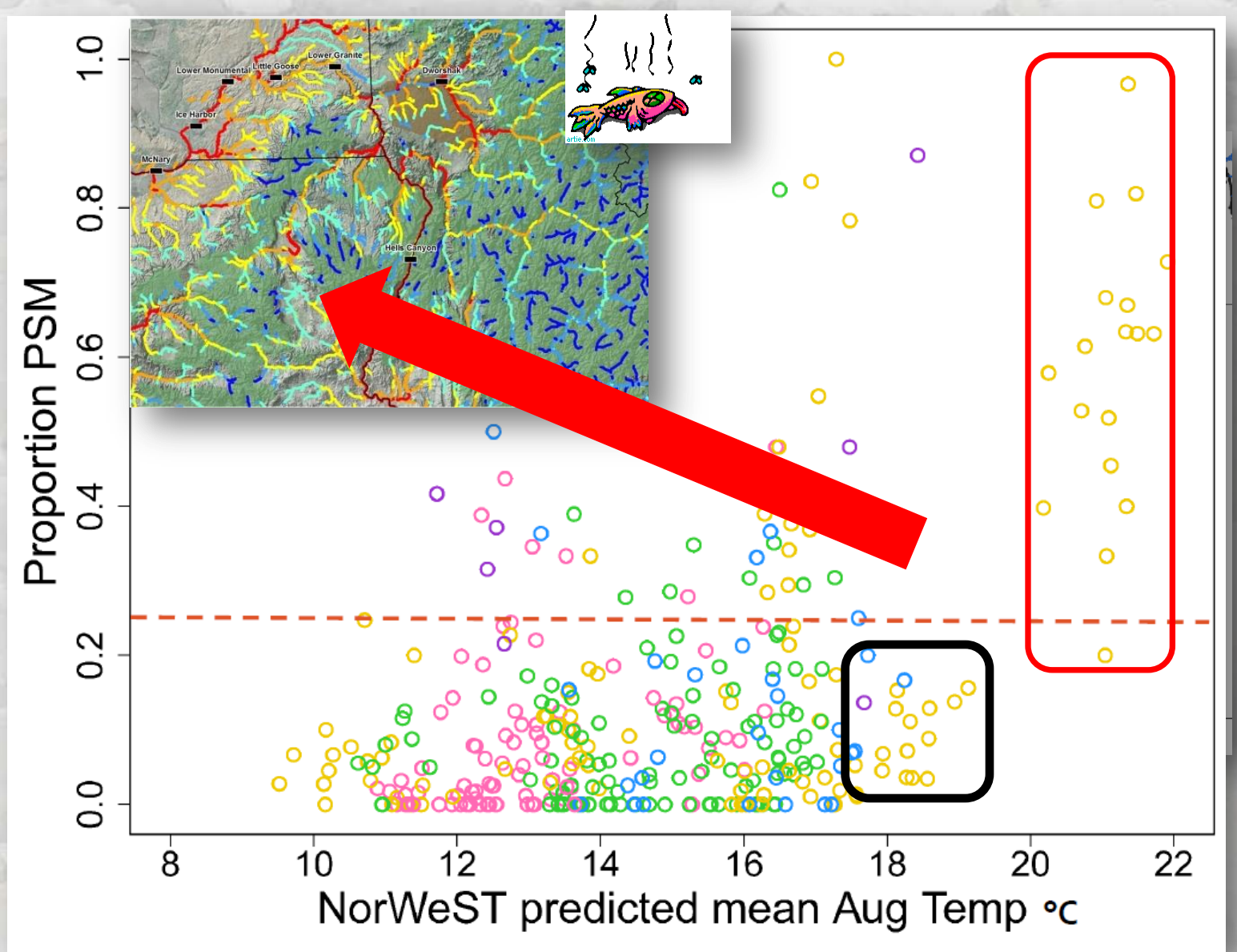




Bowerman, Keefer, & Caudill (U. Idaho)

Informing Investments with Climate Scenarios

NorWeST & Prespawn Mortality in Salmon

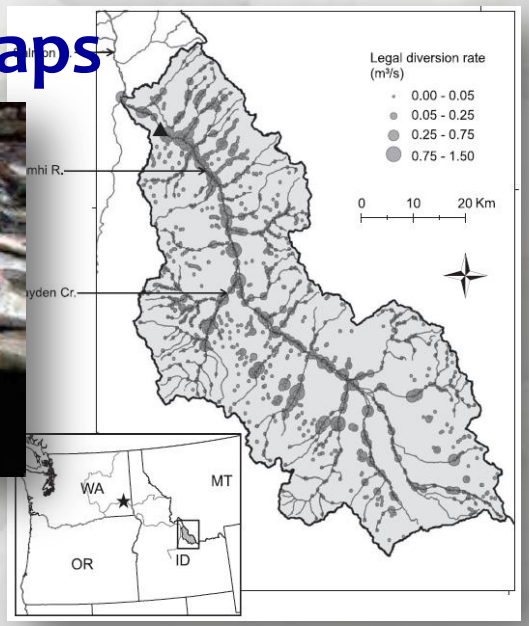


Standard Tools Once Know Where to Go

Water Rights

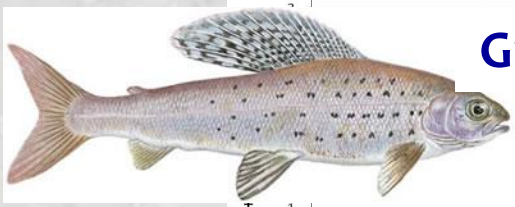
Permanent acquisitions
- minimum flows

Short-term swaps



Modernize Water Delivery Systems for Efficiency…

Landowner partnerships

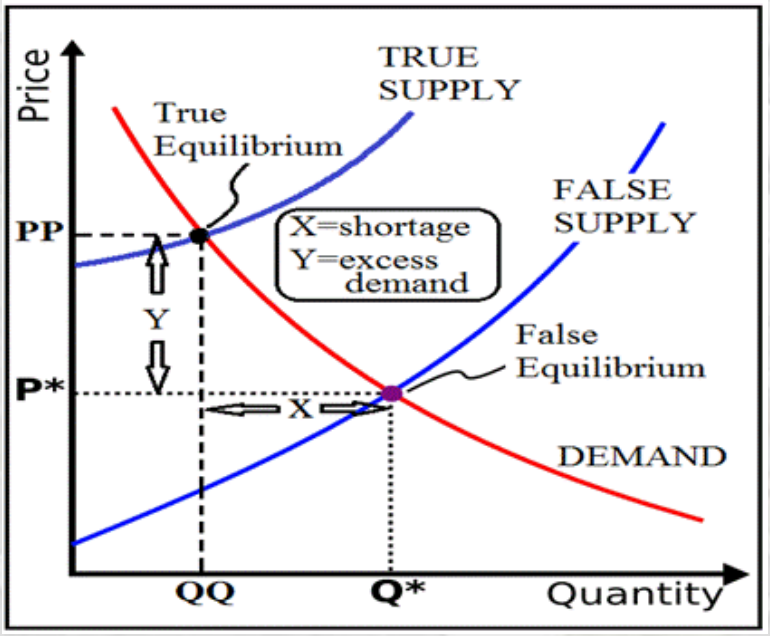


…& sometimes create win-win situations in which fish benefit

Water Markets

Can they work?

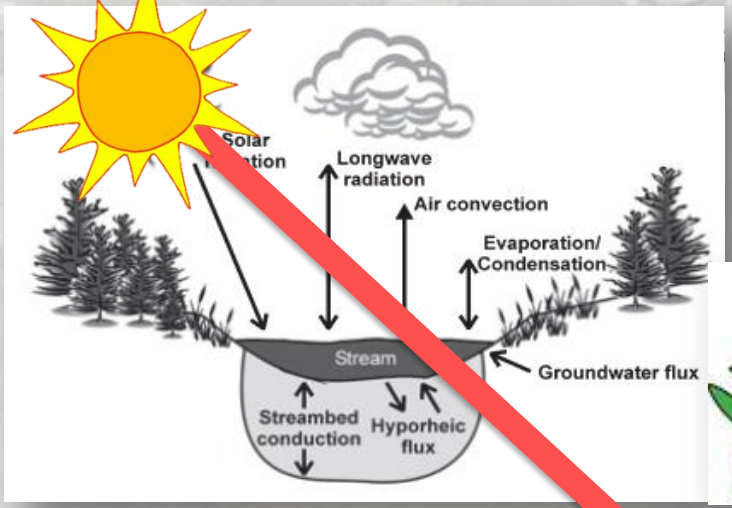
Would they create efficiencies?

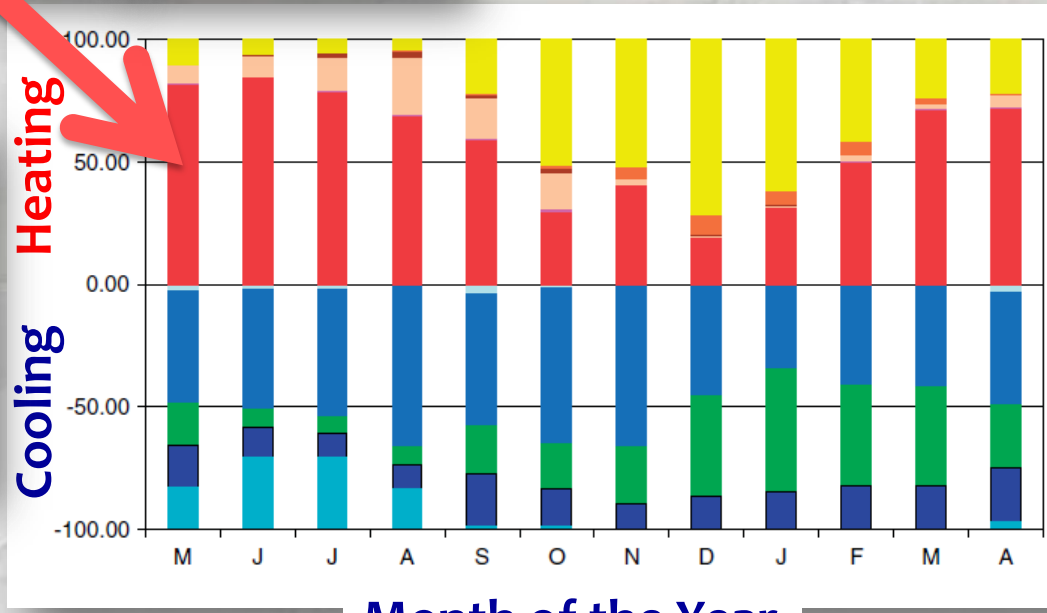


Are we growing the smartest crops in the smartest places?

Riparian Vegetation Restoration

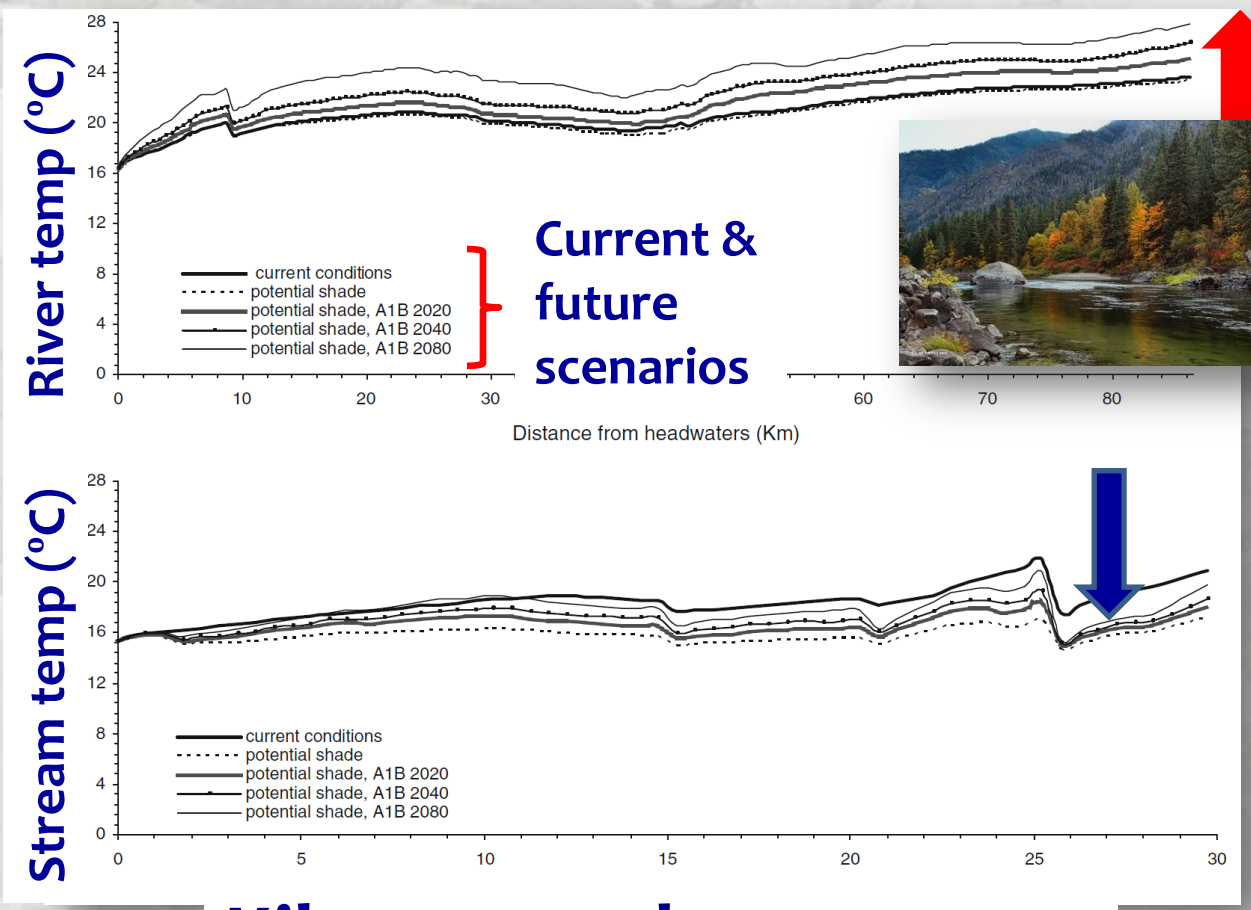
Shading is THE most important factor…





Webb et al. 2008

But Shading Doesn't Help Large Rivers



Current & future scenarios

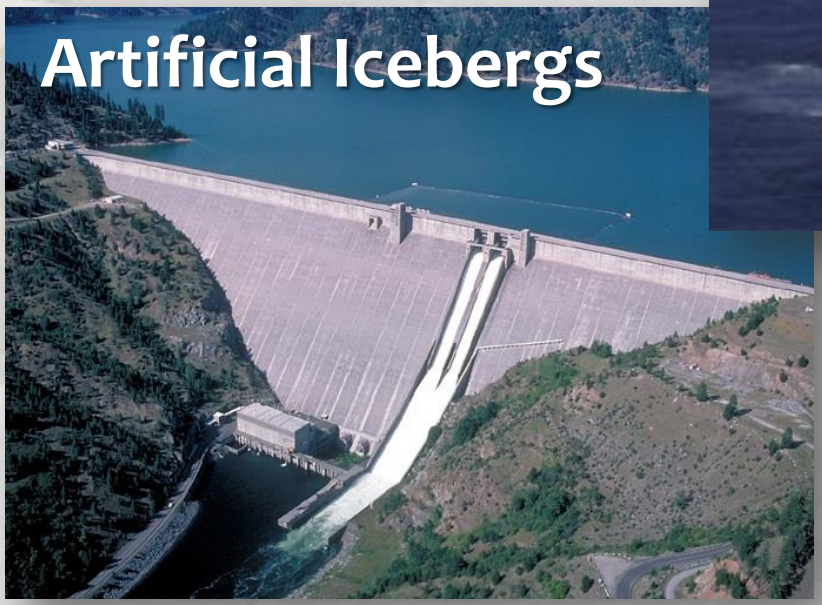
Larger river warms up with climate change despite riparian improvements

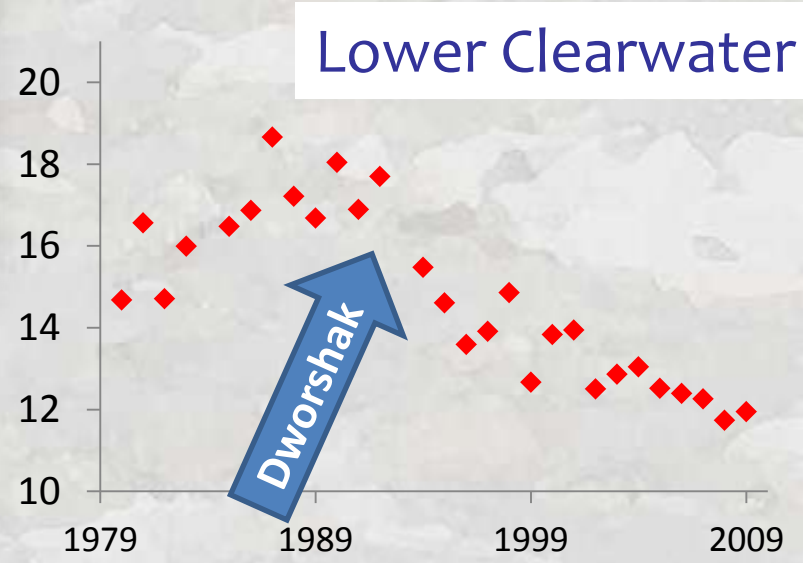
Riparian improvements make smaller stream colder even with climate change

Kilometers downstream

Cristea and Burges. 2010. Assessment of the current and future thermal regimes of three streams located in the Wenatchee River basin, Washington State: some implications for regional river basin systems. *Climatic Change* **102:***493–520.*

Options for Cooling Large Rivers are Limited…

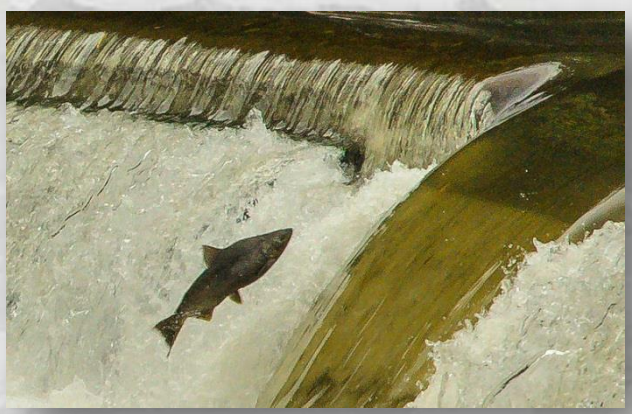


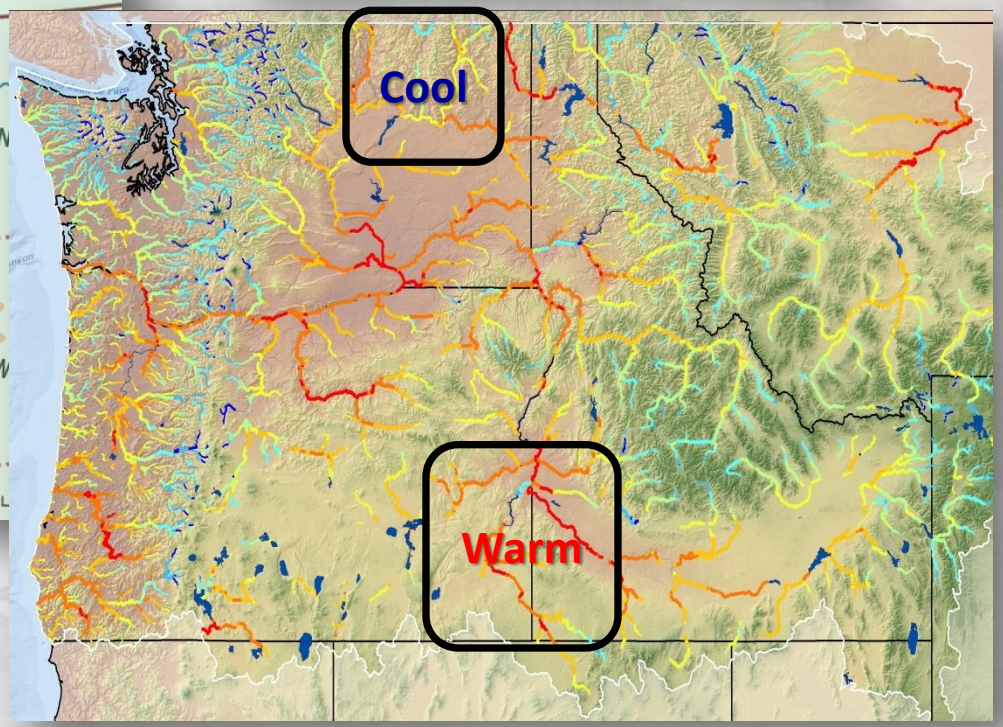


★ Deep reservoir needed for cold water creation

Fish Flows *Across* Landscapes

Restore Access to Historical Habitats that are Relatively Cool…





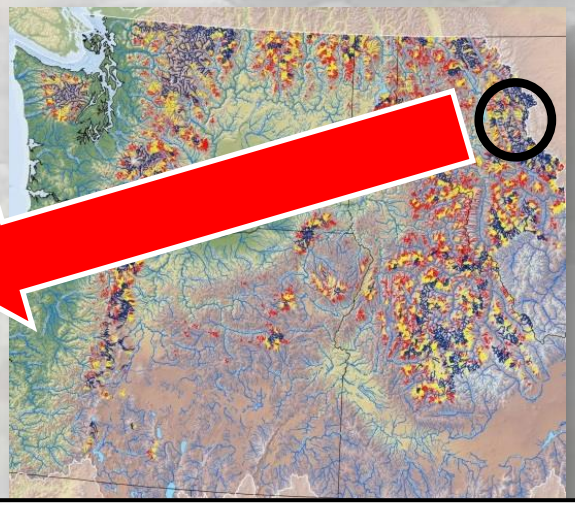
Fish Flows *Within* Landscapes

Precise species distribution models now possible

Occupancy Probability

- > 0.90
- > 0.75 to < 0.90
- > 0.50 to < 0.75
- > 0.25 to < 0.50
- < 0.25
- Slope = 10% to 15%

Climate Shield



Accurate predictions for every stream & multiple climate scenarios

5,332 >0.1 habitats

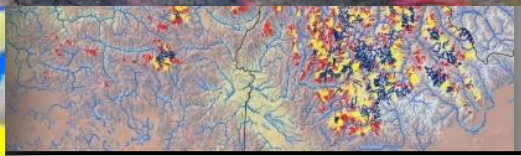
,325 >0.5 habitats

348 >0.9 habitats

Fish Flows *Within*

Precise species distrib

Highest priority barrier removal!



332 >0.1 habitats

325 >0.5 habitats

48 >0.9 habitats

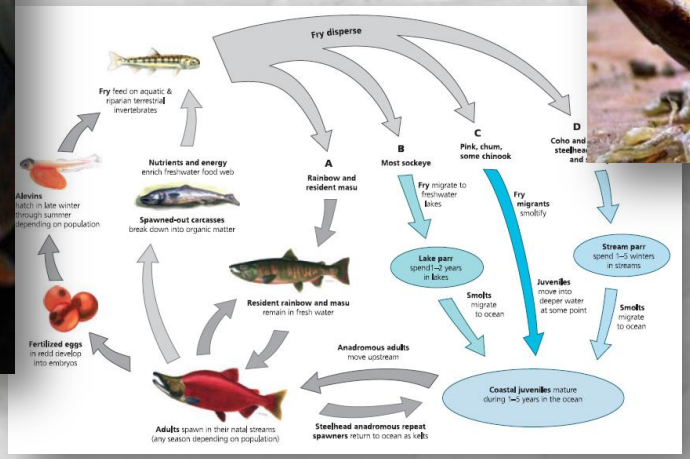
eDNA = databases & models for all stream critters

USFS National Genomics Center for Wildlife & Fish Conservation

- Pioneered the technique for salmonids
- Species specific, highly reliable (1 trout / 100 m = 85% detection)
- Field-proven protocol
- Cost: $65 sample

Mike Schwartz
Mike Young
Kevin McKelvey

Accelerate Evolution - Hatchery selection of migration timing to minimize exposure to hot seasons



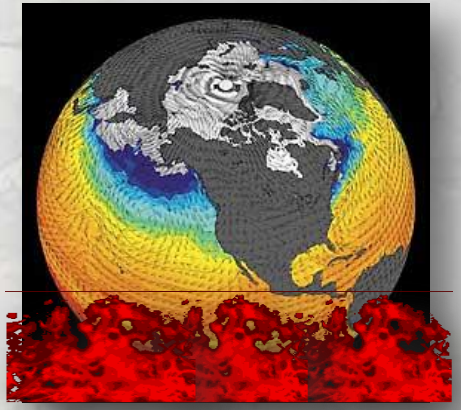
Trait	Evolutionary Potential
Heat tolerance	Low
Disease resistance	Low to moderate
Upstream migration timing	High
Spawning date	High
Emergence date	Low
Juvenile growth	Low
Downstream migration timing	?
Ocean residence	?

Crozier et al. 2008

Build Climate Information Systems that Empower Decision Makers & Local Decisions

Global climate models

Resolution: 10000s of meters

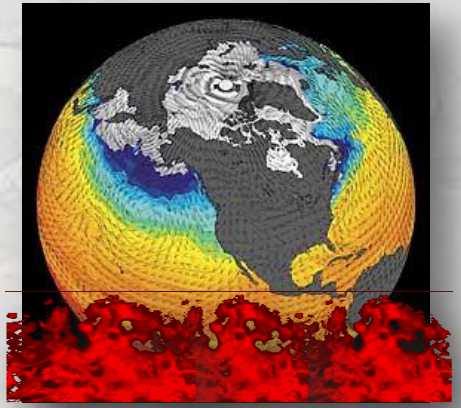


?

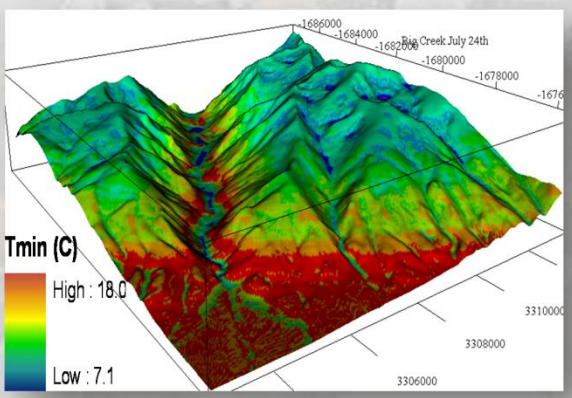
Stream reach

Build Climate Information Systems that Empower Decision Makers & Local Decisions

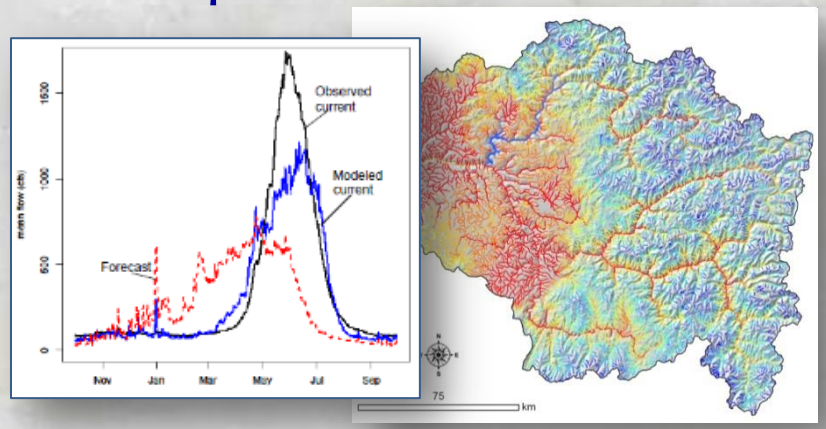
Global climate models
Resolution: 10000s of meters



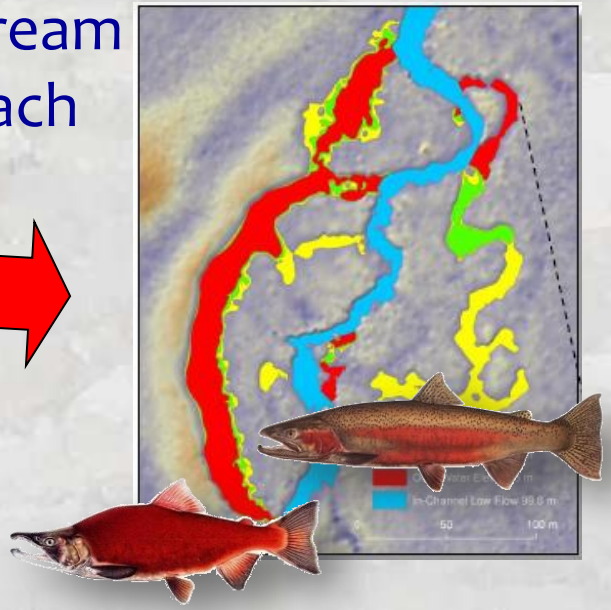
Landscape climate models
Resolution: 10s meters



River network
temperature & flow

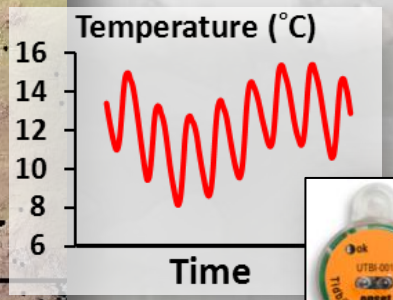


Stream
reach



Examples with Temperature Data…

>50,000,000 hourly records
>18,000 unique stream sites
>90 resource agencies

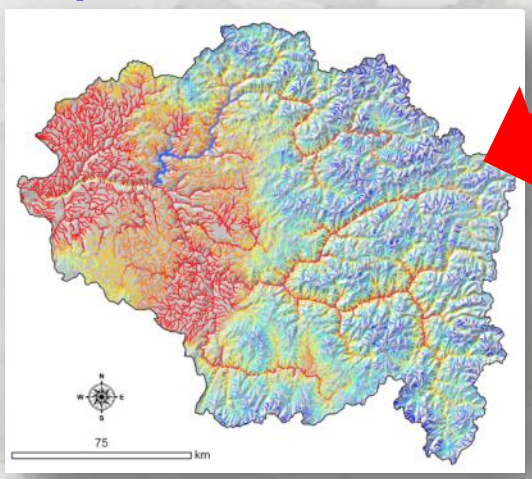


4 Years of Work:
$1,000,000
became $10,000,000

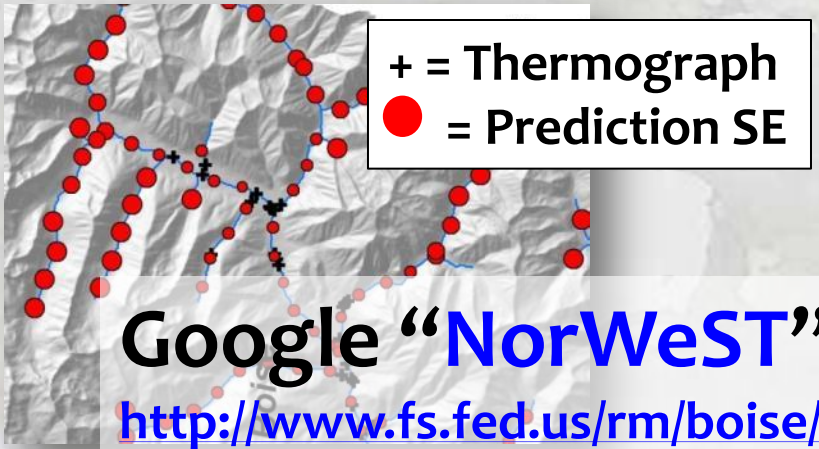
NorWeST
Stream Temp

Website Distributes Data to Aquatics Community in User-Friendly Formats

1) GIS shapefiles of stream temperature scenarios



2) GIS shapefiles of stream temperature model prediction precision

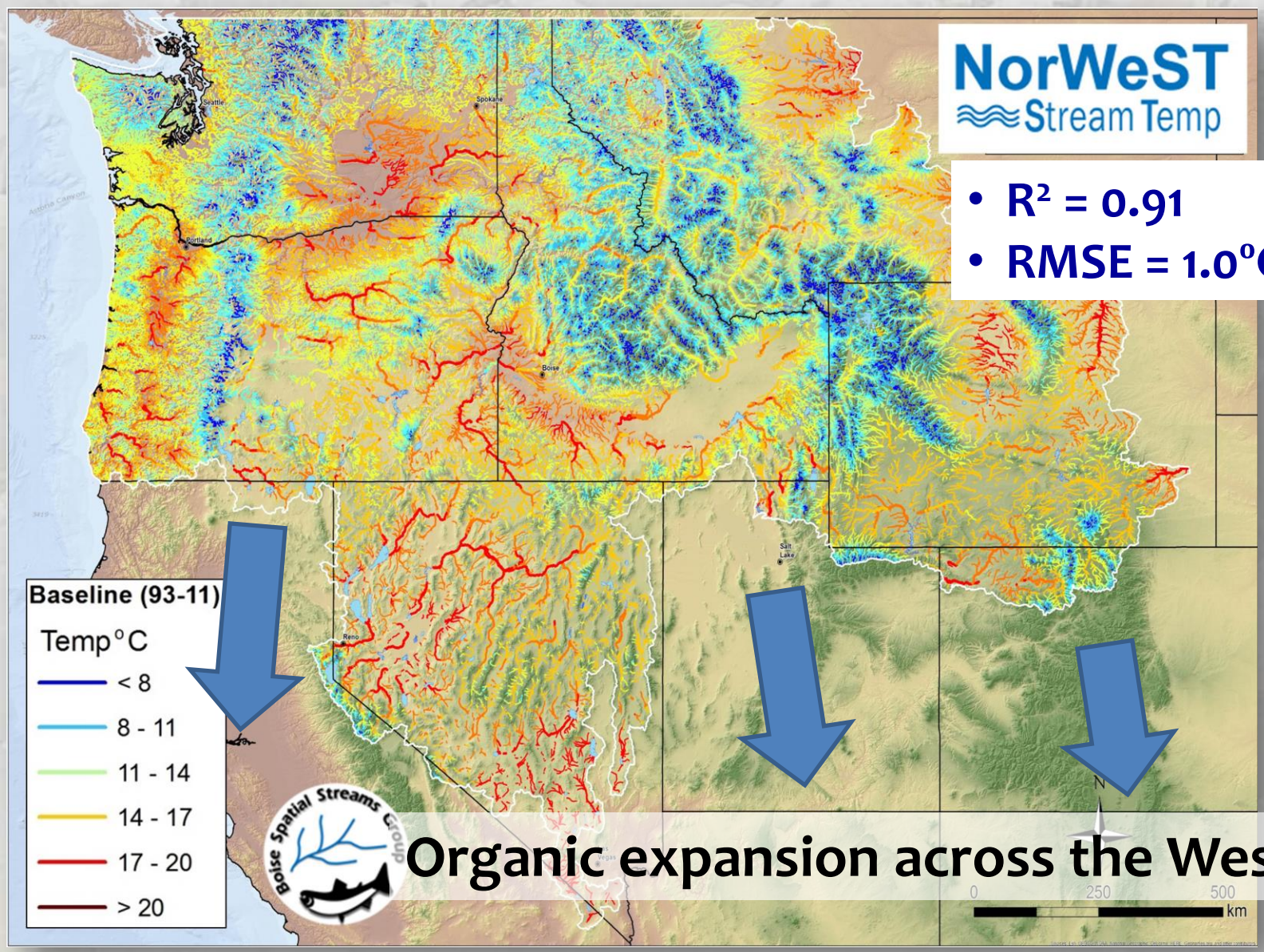


3) Temperature data summaries

Google "NorWeST" or go here…

http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml

“Information” is Most Valuable Asset

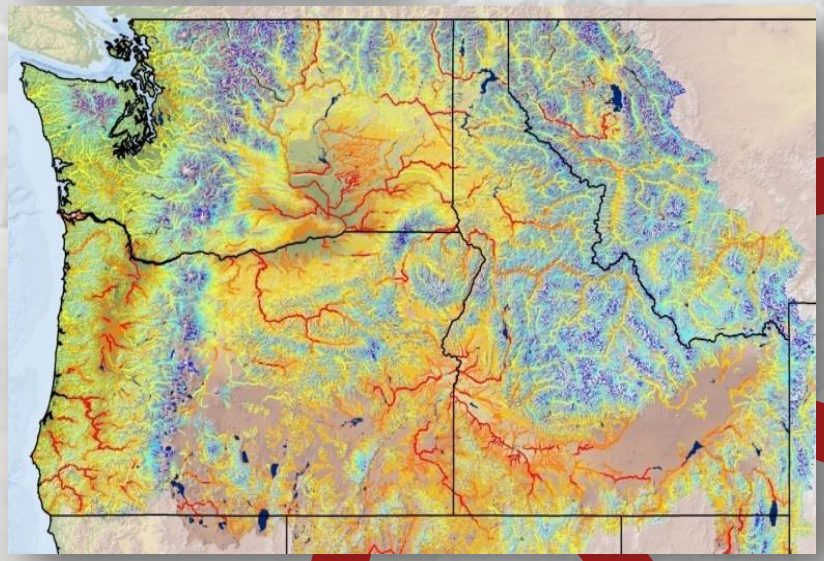


- R^2 = 0.91
- RMSE = 1.0°C

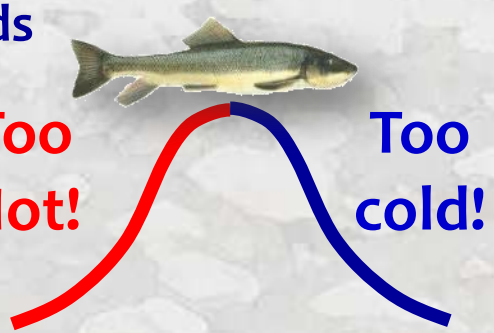
Organic expansion across the West

NorWeST Stream Temp

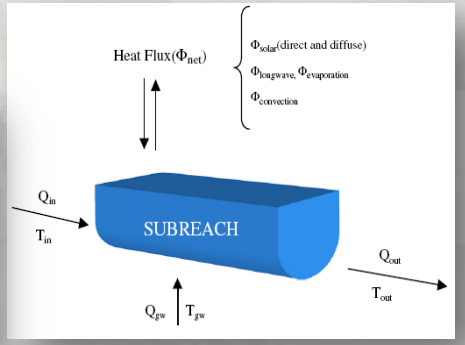
Temperature Applications

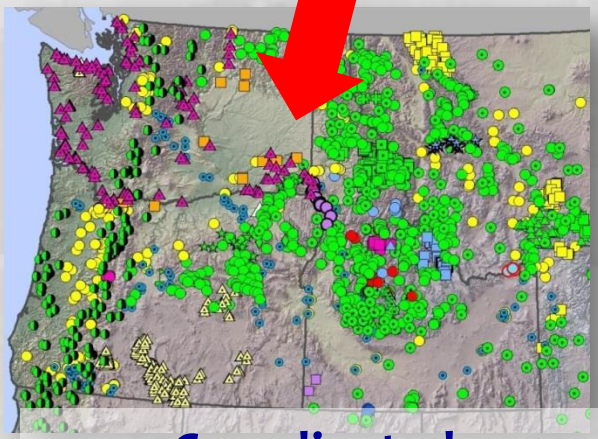


Regulatory temperature standards

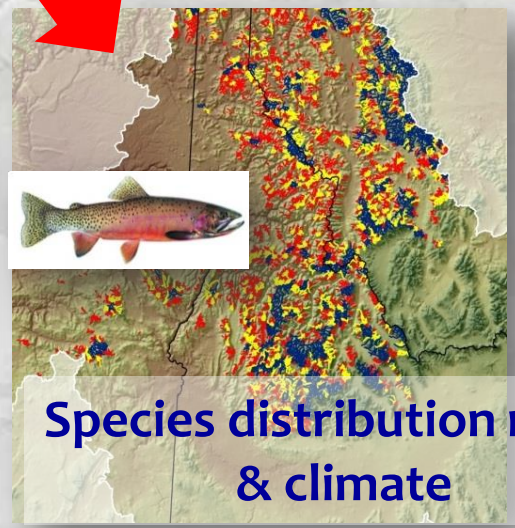


Data access accelerates temperature research





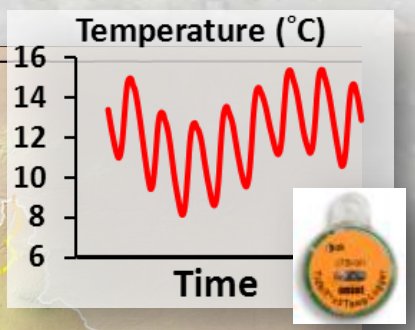
Coordinated Interagency monitoring



Species distribution models & climate

Database Query Revealed Monitoring Gap

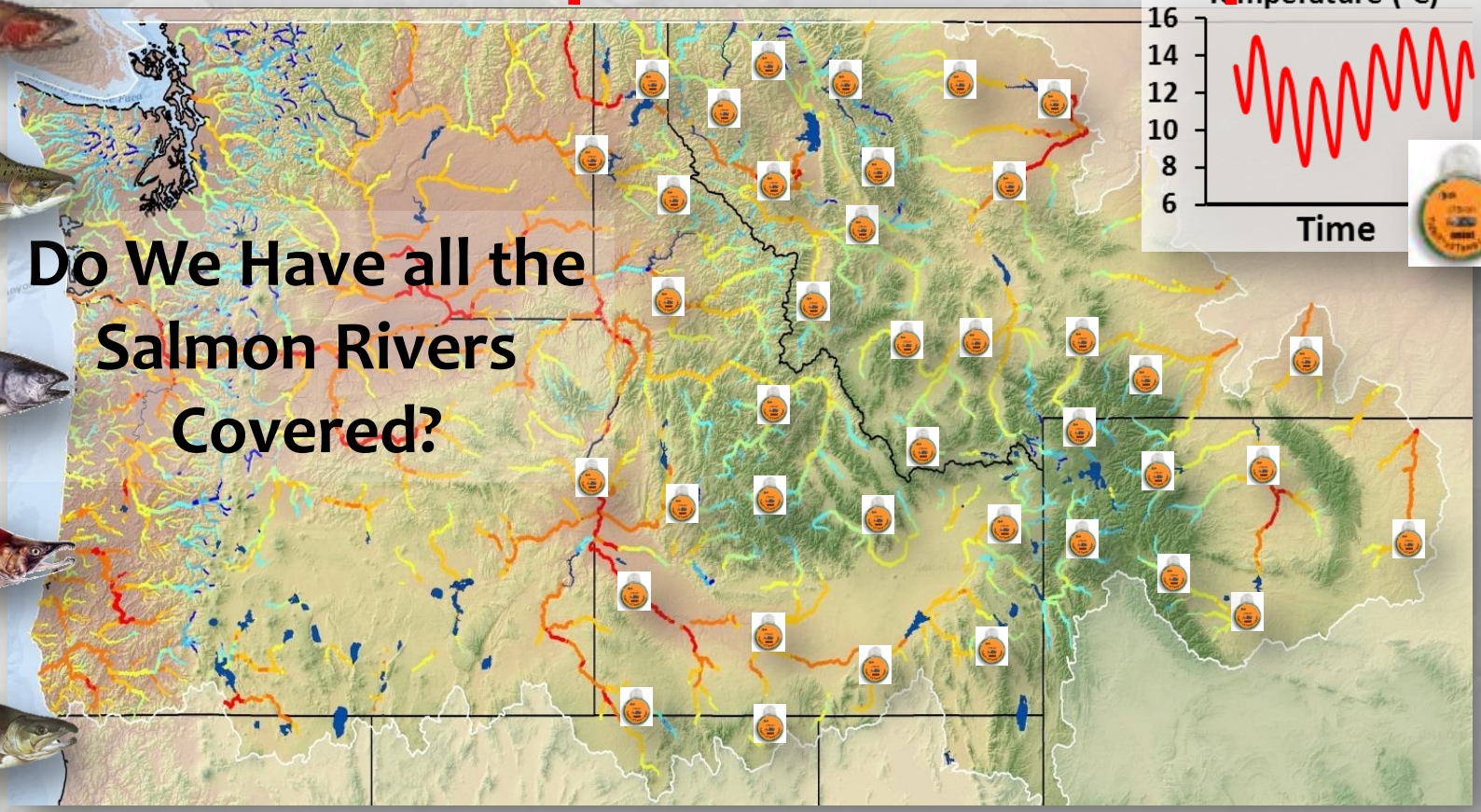
Unregulated rivers lacked annual temperature data monitoring



So as a side project, we set up a river monitoring network the last few years

NoRRTN: Northern Rockies River Temperature Network

~240 sites on 80 rivers

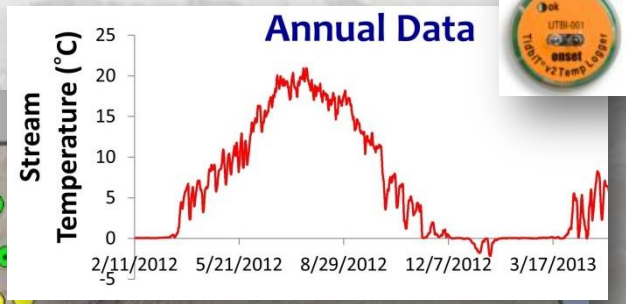


Do We Have all the Salmon Rivers Covered?

Grassroots Monitoring is Increasing…

>4,000 annual sites in Pacific Northwest

>300 new sites last year



>50,000,000 hourly records every year!

How to Capture These Data?

NEZ PERCE TRIBE TREATY OF 1855

North Fork John Day Watershed Council

DEPARTMENT OF ECOLOGY State of Washington

IDAHO FISH & GAME

IDAHO POWER.

USGS science for a changing world

NOAA Fisheries

OREGON Fish & Wildlife

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

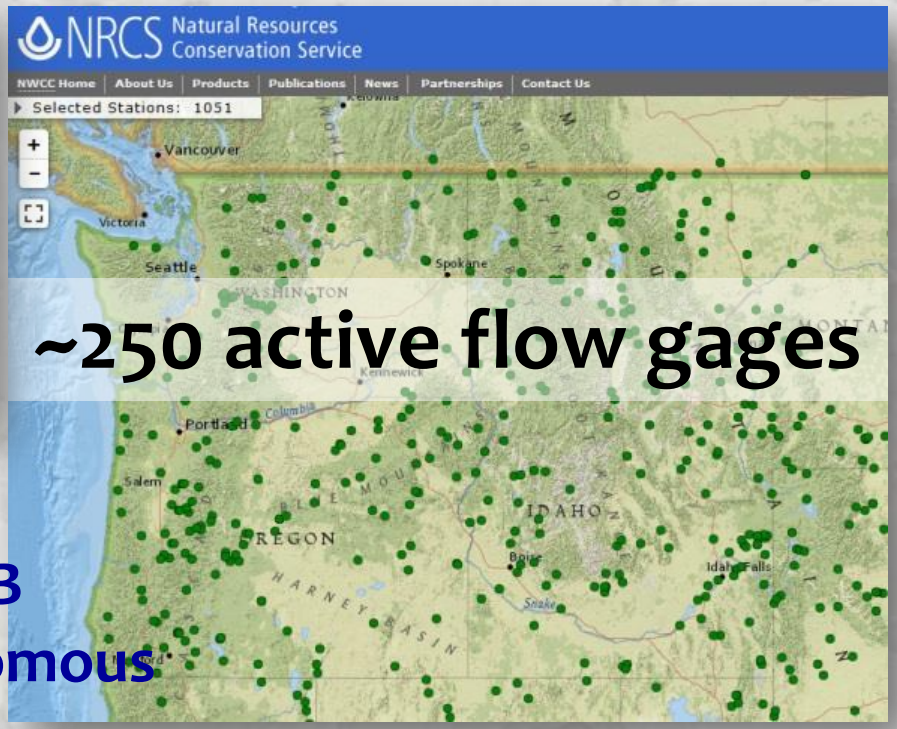
Washington Department of FISH and WILDLIFE

COLUMBIA RIVERKEEPER

KALISPEL TRIBE OF INDIANS

Same Things Possible with Flow Data

But Monitoring Network is Very Sparse



~250 active flow gages

Huge Spatial Uncertainty

~200,000 stream km in CRB

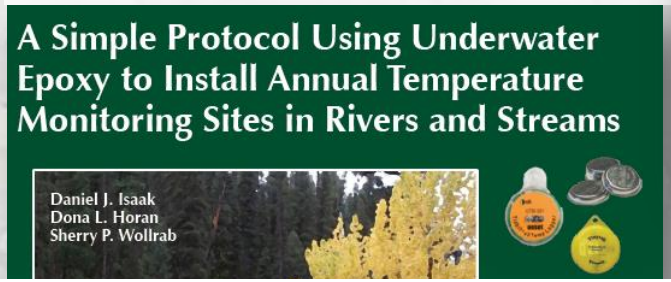
~20,000 stream km anadromous

Many hydrologic models, but all use same small datasets…

Stream Climate Monitoring Networks

Standard Protocols & Inexpensive Sensors

Stream Temperature

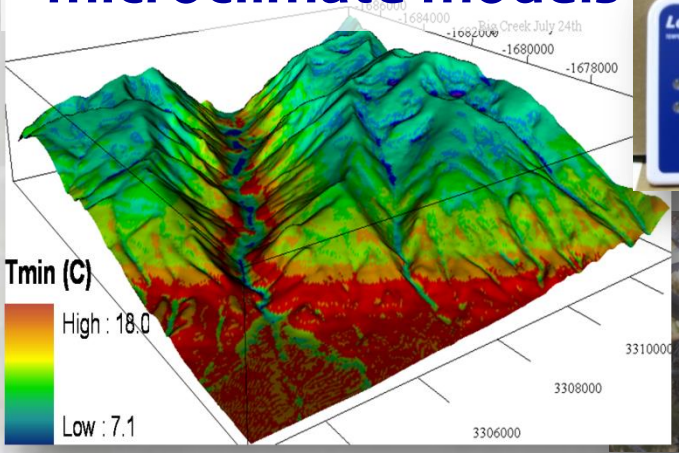


$130 = 5 Years of Data

Stream discharge

$299 sensor

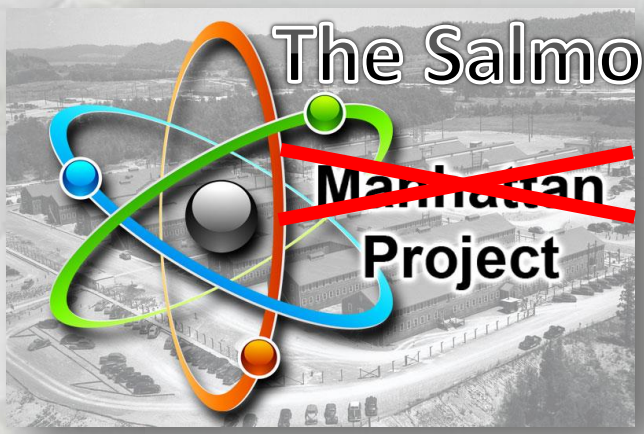
Air Sensors (~$50) for microclimate models



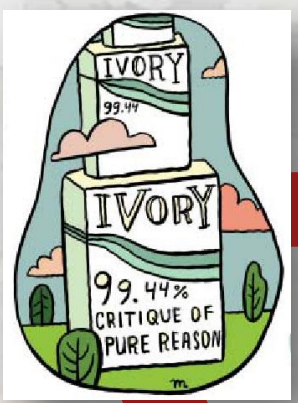
Sponsor a Salmon Climate Summit

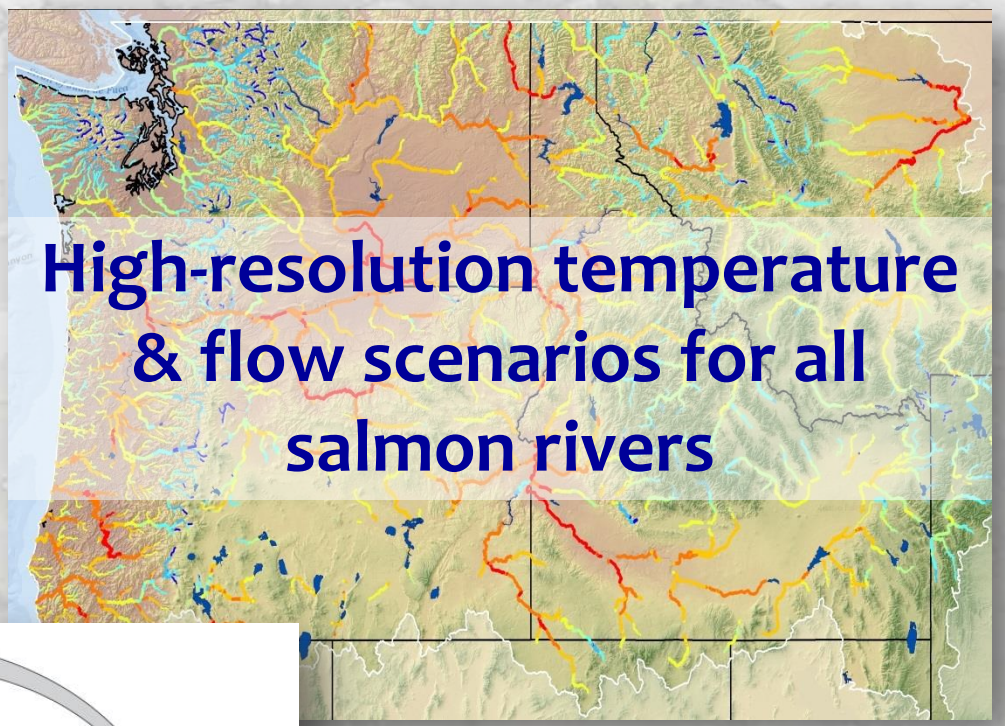
World's best salmon researchers & climatologists are within a few hours

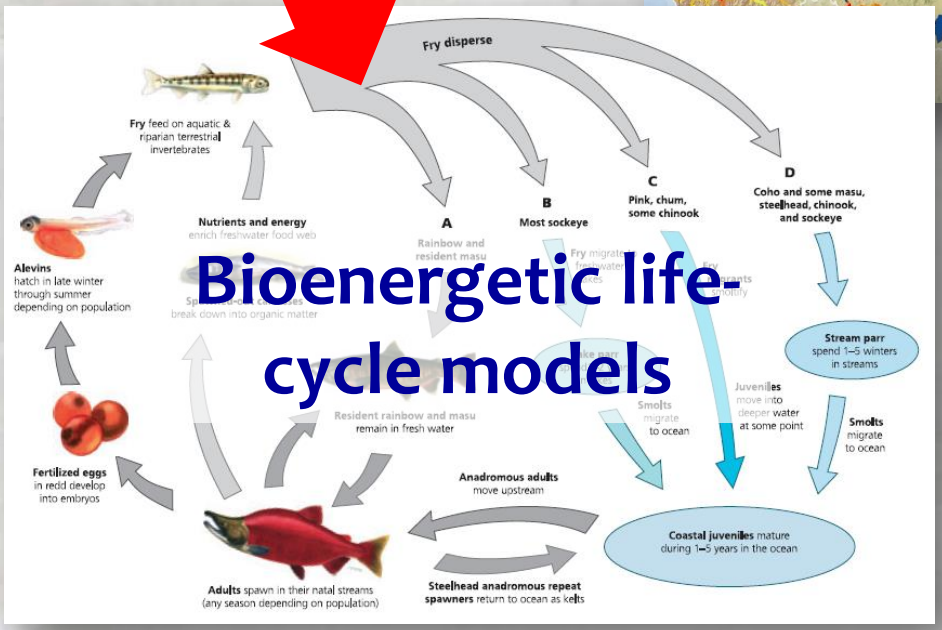
Lock them in a room until a detailed research agenda exists



Reinstate the BPA Innovative Projects Grant Process







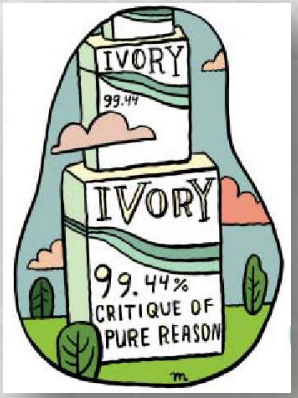
Bioenergetic life-cycle models

Make researchers compete & create

Create a "Virtuous Cycle" of Information

Many stakeholders

"Boots-on-the-Ground"

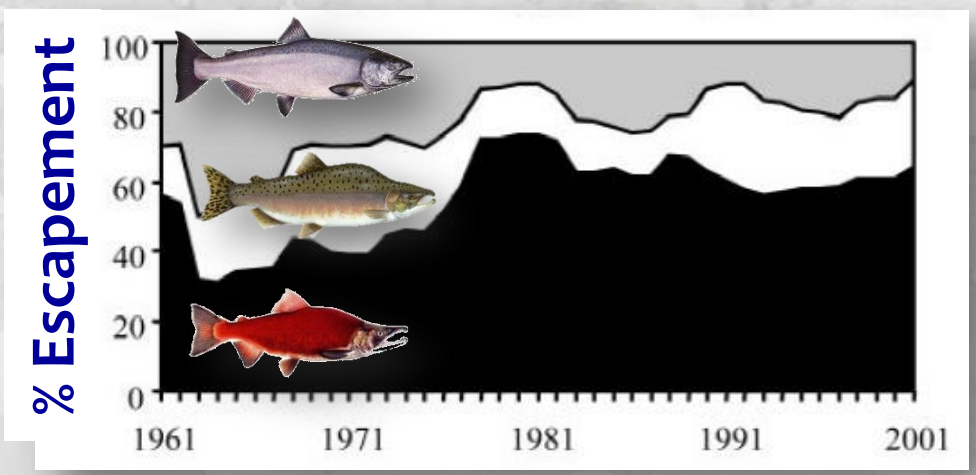


Research develops databases & relevant information

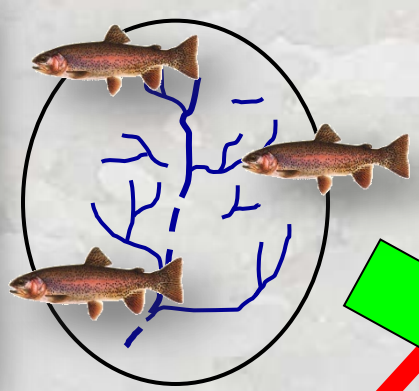
Mountains of data

Public Relations – Setting Expectations

Biocomplexity will buffer us…



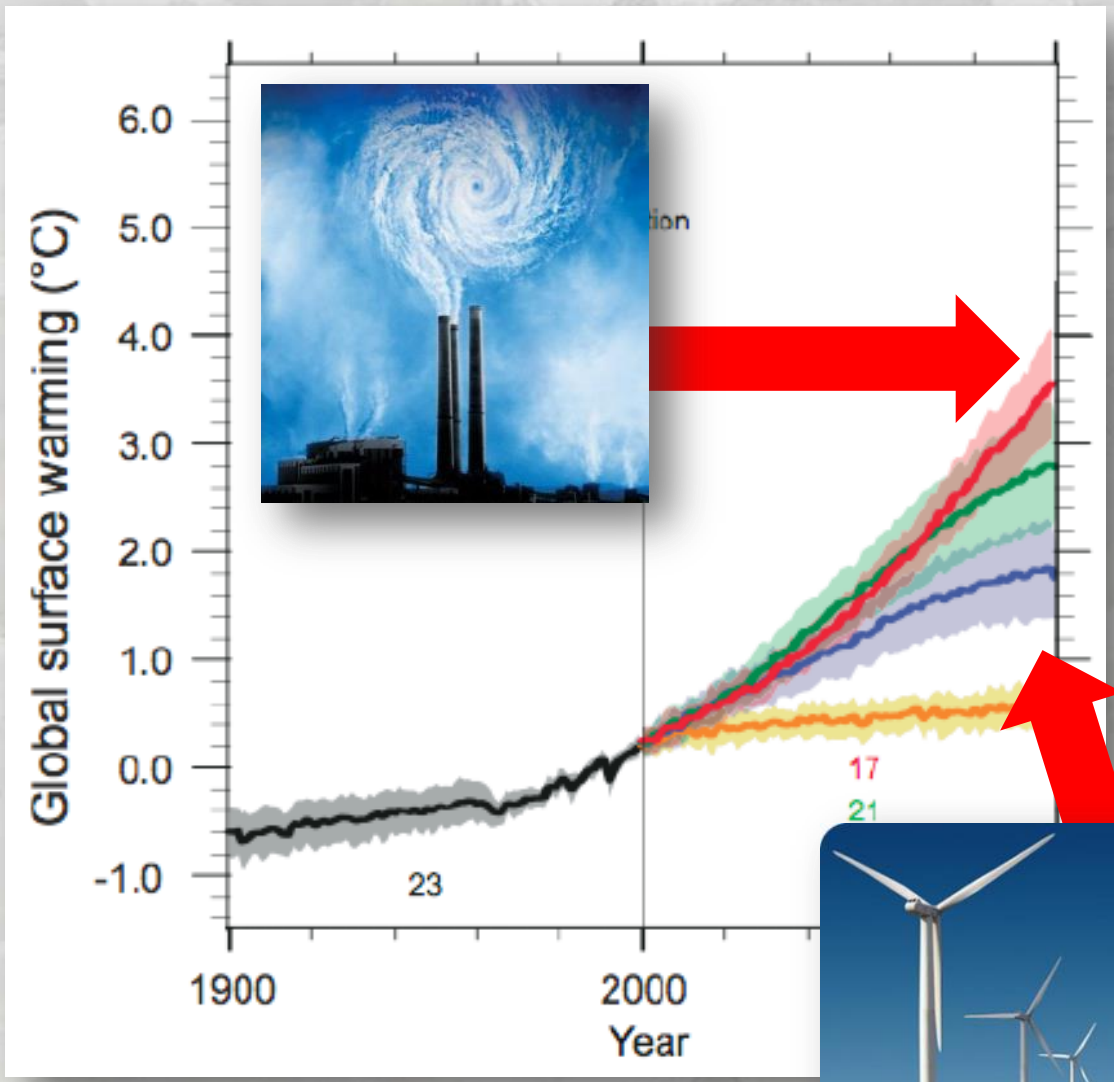
…but we can't save everything



Sorry Charlie

Thresholds Beyond Which Some Populations are "Walking Dead"

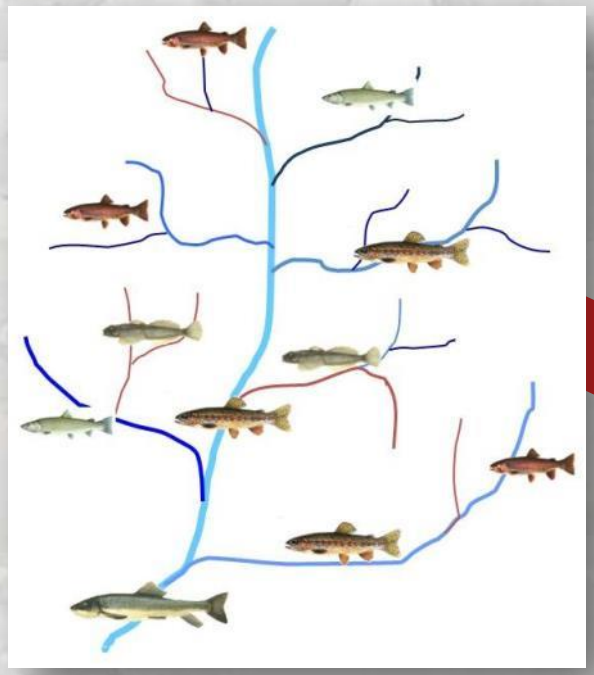
Make Tough Choices… as Information Allows



The longer we wait, the more painful & expensive the options become

The 21st-Century will Be a Transitional One

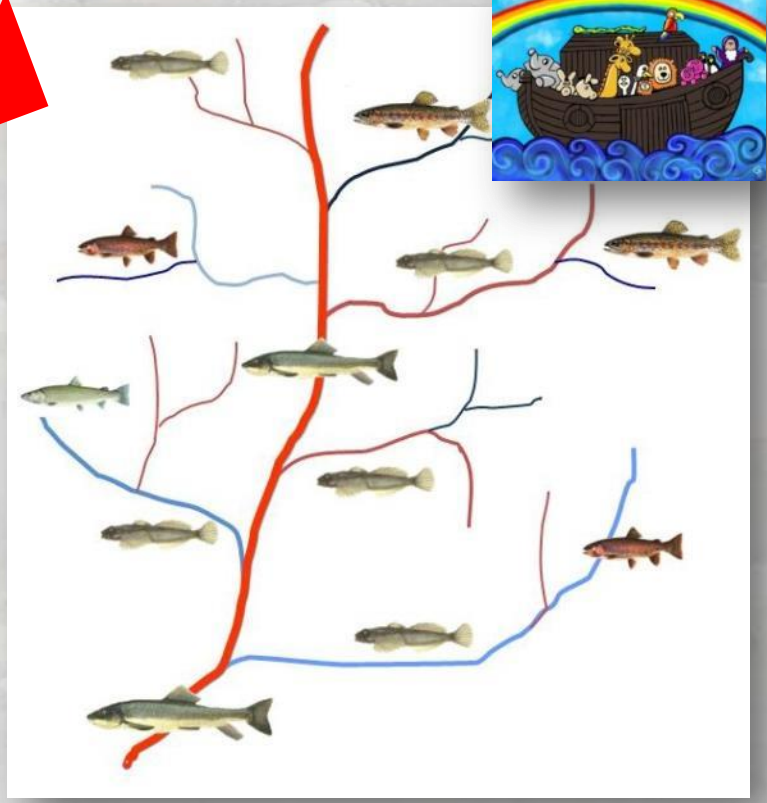
Current Status



Set Goals & Create Culture of Adaptive Management

Desired Future Status

Perhaps fewer, but happy & stable populations of target species




Global Warming Is ...
NOT COOL!
The End